Department of Transport and Regional Development
The Federal Office of Road Safety

Vehicle Occupant Protection:
Four-Wheel-Drives, Utilities and Vans

Brian Fildes, Sally Kent, John Lane, Jim Lenard,
Peter Vulcan

Monash University
Accident Research Centre

Australian Government Publishing Service
Canberra

ISBN 0 642 51229 9

Produced by the Australian Government Publishing Service

DEPARTMENT OF TRANSPORT AND REGIONAL DEVELOPMENT

FEDERAL OFFICE OF ROAD SAFETY

DOCUMENT RETRIEVAL INFORMATION

Report No.	Date	Pages	ISBN	ISSN
CR 150	June, 1996	68	0 642 51229 9	0810 - 770X

Title and Subtitle

Vehicle Occupant Protection: Four-Wheel-Drives, Utilities and Vans

Authors

Fildes B.N., Kent S M., Lane J.C., Lenard J. & Vulcan A.P.

Performing Organisation

Monash University Accident Research Centre
Wellington Road, Clayton, Victoria, 3168, Australia

Sponsored by / Available from

Federal Office of Road Safety
Project Officer: Keith Seyer
GPO Box 594
CANBERRA ACT 2601

Abstract

Although the number of 4WDs, utilities (not passenger car derivatives) and forward control vans in Australia is increasing, very little is known about the occupant protection they offer in real world crashes. Furthermore, these vehicles are not subject to the full range of design rules applicable to passenger cars and their derivatives. The aim of this study was to examine the extent and patterns of injuries sustained by occupants of 4WDs, utilities and vans in crashes where the vehicle was classified as "written-off", and to ascertain the need for more stringent regulations governing this group of vehicles. The study involved three main stages: (1) a review of the international literature covering the crash types and crash performance associated with these vehicles (or their closest overseas equivalents); (2) analysis of two mass databases covering casualty crashes in NSW and fatal crashes throughout Australia where vehicle type was coded; and (3) a detailed investigation of 144 "write-off" crashes involving roughly equal numbers of post-1985 4WDs, utilities and vans.

The majority of crashes were found to be frontal ones, although rollovers were over-represented (mainly for 4WDs) by comparison with the crashed passenger car file. The crashes sampled in this study were of low severity compared to the sample of passenger car crashes, as reflected by relatively low impact velocities (modal Delta-V of 18-24 km/h), few instances of entrapment or ejection, and low levels of injury (84% either uninjured or minor injury not requiring hospitalisation). Minor (AIS<2) injuries to the upper limbs through contact with seat belts, steering wheels and instrument panels were most common, although whiplash injuries were also prevalent (approximately one third of all drivers). Injuries to the upper and lower leg through contact with the instrument panel and floor were over-represented among van drivers, consistent with the preponderance of frontal crashes and the reduced crumple space in these vehicles. Head and spinal injuries caused by roof contacts were slightly over-represented among drivers of 4WDs and utilities, consistent with their over-involvement in rollover crashes. Countermeasures relating primarily to improved steering assembly, restraint systems and instrument panel construction are discussed, and recommendations are made for an extension of the study to include more hospitalised cases.

Keywords

Safety, Accident, Vehicle Occupant, Injury, Four-Wheel-Drive, Passenger Vans, Utilities, Design Rules, Crash Types

Contents

List of Tables

List of Figures

Preface

The Federal Office of Road Safety commenced a review of the level of occupant protection provided by off-road passenger vehicles and light commercial vehicles in 1992.

As part of this review, a study was commissioned by FORS with the Monash University Accident Research Centre to examine the occurrence of injuries to occupants of these vehicle categories This report details the outcomes of that study.

In parallel, a review group was set up with industry to explore ways to improve the level of occupant protection provided by these vehicles. This included development of an agreed timeframe within which to introduce changes to the Australian Design Rules.

FORS Report OR 17 - "Review of Occupant Protection in Light Commercial, Off-Road and Forward Control Passenger Vehicles" draws together the research conducted as part of this review and should be read in conjunction with this report OR 17 also details the changes to the Australian Design Rules which bring the level of occupant protection of these vehicles up to that provided by passenger cars. Four-wheel-drives sold in Australia already comply with the only rollover standard available, US Federal Motor Vehicle Safety Standard 216.

Acknowledgements

The authors are indebted to the Federal Office of Road Safety, Commonwealth Department of Transport and Regional Development, Australia, for their sponsorship, interest and assistance with this project.

A study of this magnitude could not have been undertaken without the help and co-operation of a large number of people. In particular, the valuable assistance of other Accident Research Centre staff Srs. Nicole O'Meara and Barbara Fox in collecting the injury data and Mr. Tri Minh Le, Ms Sandra Gantzer and Mr. David Dyte in conducting the analyses was greatly appreciated.

The study team acknowledge the generous assistance of the eleven study hospitals, their co-ordinators, and their staff in providing access to patients and medical records, namely the Alfred, Austin, Ballarat Base, Box Hill, Dandenong & District, Geelong, LaTrobe Regional, Monash Medical Centre, Royal Melbourne, PANCH, and Western Hospitals. We are grateful, too, to the many vehicle occupants who kindly agreed to participate in the study during their time of trauma.

To Fowles Auction Group, and in particular Mr. David Grey, for providing us access to their vehicles and allowing us to work in their yard, we are especially grateful. To the insurance companies RACV Limited, GIO Insurance and AAMI, who willingly provided us details on these crashed vehicles, we are eternally thankful. The Victorian Police were always ready to assist either in locating the vehicles, providing details on the crash, or providing access to vehicles stored in their yards and we are extremely grateful to the many members of the police force who assisted with the study.

We would also like to thank the NSW Roads & Traffic Authority for allowing us access to their data on relevant casualty crashes and to the Federal Office of Road Safety for undertaking a number of analyses on the fatal file. We are also grateful to Intstat Statistical Data Analysts, especially Robin Attewell, for undertaking these analyses on behalf of FORS.

Executive Summary

Four-Wheel-Drives, Cab-Chassis Utilities, and to a lesser extent, Vans, are becoming an increasing proportion of the vehicle fleet as many people choose to drive these vehicles as an alternative to passenger cars. In 1992, for instance, sales of 4WDs and Utilities represented 18.1% of all new vehicle sales, compared with 16.7% in 1991.

While a number of current Australian Design Rules apply to these vehicles (such as ADR 10/01 for steering column intrusions), these vehicles are not classified as "passenger cars or derivatives", and hence are not subject to the full range of design rules that currently apply to passenger cars in this country.

AIMS & STUDY TASKS

The objectives of this study were to examine the extent and patterns of injuries occurring to occupants of these vehicles and the need for more stringent regulations for this growing fleet of alternative passenger vehicles.

Three tasks were undertaken to meet these aims. First, a review of mainstream occupant protection literature was conducted to highlight previous published findings in this area.

Second, an analysis of six years of New South Wales tow-away casualty data and two years fatality data on the national fatal file was then carried out to illustrate the extent of the problem and patterns of injuries sustained by seriously injured occupants of passenger cars, four-wheel-drives (4WDs), vans and light trucks/utilities.

Finally, a thorough examination of 140 vehicles (4WDs, Vans & Utilities) which had been written-off as a result of a road crash with another vehicle or a fixed object was undertaken to provide a more detailed picture of the extent of damage, the injuries sustained by the occupants and the sources of these injuries from within or outside the vehicle.

MASS DATA ANALYSIS

The main findings from the mass data analysis of casualty and fatal crash data were as follows:

- Four-wheel-drives, utilities and vans involved in casualty crashes in NSW over the years 1987-1992 accounted for roughly 10% of road trauma to vehicle occupants.
- Four-Wheel-Drives, compared with other vehicle types, were over-involved in casualty and fatal crashes occurring in high speed zones (≥75km/h), but were particularly over-involved in rollover crash configurations in both high and low speed zones.
- Rollover crash configurations were 12 times more likely to occur in high than low speed zones, and high speed zone rollovers accounted for 80% of injuries sustained in rollover crashes.
- While there were no consistent differences in overall injury severity between the vehicle types, 4WD occupants were marginally more likely to die in a high or low speed rollover crash than car or van occupants in equivalent crashes.

- Drivers of 4WDs involved in casualty or fatal crashes were more likely to be male and aged between 26 and 55 years; additionally, occupants of 4WDs were more likely than other vehicle occupants to be unrestrained and hence ejected.
- Passenger vans were over-involved in fatal outcomes in head-on crashes in low speed zones (< 75km/h) and their occupants were more likely to be trapped in the vehicle in these crashes. This is probably because of the more limited crumple space available in passenger vans.
- Head and chest injuries were the predominant cause of death in fatal crashes.
- Occupants of 4WDs killed in rollover crashes were slightly more likely to sustain a severe spinal injury but less likely to sustain a severe chest injury by comparison with passenger car occupants in equivalent crashes.

CRASHED VEHICLE STUDY

The pattern of crash types in the crash vehicle file mirrored those from the mass databases with 4WDs being over-involved in rollovers - nearly half of the 4WD crashes were rollovers. The mean delta-V value for 4WD crashes (35.5 km/h) was lower than that observed in the crashed passenger car study (45.4 km/h) suggesting that these crashes were of relatively low severity, probably due to the vehicle-based entrance criteria. Observed belt-wearing rates were extremely high among this sample of relatively minor crashes (98%) and no occupants were ejected.

The vehicle-based entrance criteria and the relatively small number of cases (144) probably also contributed to sparse injury data and the low levels of injury severity observed (84% minor or no injuries). Further, the high number of "driver-only" vans and utilities in the sample resulted in very small numbers of occupants in other seating positions. The lack of major injuries and the small number of front-left and rear passengers in particular were problematic for this study. Nevertheless, some interesting trends were apparent in the data for drivers, and these are presented below.

Upper limb injuries were the most common injury among drivers of 4WDs, vans and utilities alike, but were relatively minor (only 2% or less with AIS > 2). These injuries were most often caused by contact with seat belts, the steering wheel and the instrument panel. Injuries to the thigh, knee and lower leg were also quite common, particularly among van drivers, and usually the result of instrument panel or floor contacts

Non-severe neck injures, mainly whiplash, were a notable feature of the injury pattern, with about one quarter of the drivers in each vehicle category sustaining one of these injuries. Whiplash injuries were typically from crash forces or were seat belt induced. Most of the head and chest injuries observed here were relatively minor, caused by contact with the steering wheel, side glazing, door panel or the roof.

Serious injuries, although a rare occurrence, were more prevalent among van drivers, particularly by comparison with 4WD drivers, only one of whom sustained a serious injury(AIS > 2).

Extremely small numbers prevented an analysis of injuries and injury sources for unrestrained, ejected, or trapped occupants.

POTENTIAL COUNTERMEASURES

While the findings were not particularly robust, there were some suggestions of suitable countermeasures to reduce the injuries observed in the crashed vehicle study. Many of these measures have already been suggested from a previous study (CR95) for passenger cars.

STEERING ASSEMBLY: The steering wheel and assembly has been shown to inflict injury to drivers of these special purpose cars. This is in spite of the fact that 98% of the occupants whose belt wearing status could be determined were properly restrained. Steering wheel related countermeasures worthy of consideration include supplementary air bags, belt tighteners and webbing clamps, padded steering wheels, or no steering wheel at all.

IMPROVED RESTRAINT SYSTEMS: The need for improvements to existing seat belt systems was noted in CR95 for passenger cars and is again highlighted in the injury and contact source findings for this study since upper limb injuries caused by seat belts were the most common. Possible improvements to existing seat belt systems are better seat belt geometry, belt tighteners and webbing clamps, improved front seat design, better positioning of seat belt stalks, seat belt interlocks, as well as other incidental belt improvements.

THE INSTRUMENT PANEL: The instrument panel assembly was a well documented problem area for front seat occupants of current generation passenger cars and was also a cause of significant lower limb injury in this study. There are several possible countermeasures currently available to minimise or alleviate these injuries, such as the use of knee bolsters, improved padding, reduced protrusions, and the use of less injurious instrument panel materials that are more energy absorbing and less likely to shatter.

THE NEED FOR VEHICLE REGULATIONS

Special purpose vehicles such as 4WDs, vans and utilities are not currently subject to the full set of Australian Design Rules that apply to passenger cars and their derivatives. In particular, the only frontal crash requirement is for these vehicles to comply with ADR10/01 which specifies maximum steering column intrusion levels. Moreover, there is no current rollover requirement such as a roof strength test for any passenger vehicle (other than buses) sold in Australia.

Given the increasing use of 4WDs vans and utilities for private use as alternatives to passenger cars, it could be argued that they should also be expected to provide similar levels of occupant protection as passenger cars. Thus, a strong case could be mounted for all these special purpose vehicle types to be similarly regulated.

In particular, they should at least be required to meet the new dynamic frontal crash performance requirement ADR69 as well as side impact regulations, either current or proposed for the future.

Given the preponderance of rollovers among 4WD vehicles, it would seem desirable for these vehicles in particular to have to meet a roof strength requirement as well, although the form of this standard may require further consideration.

FURTHER RESEARCH AND DEVELOPMENT

This study highlighted a number of areas requiring further research. Most notably, these findings would be more robust if more data was available on those seriously injured in crashes involving these vehicles. In addition, the cost-effectiveness of many of these measures needs to be established for these vehicles. It had been hoped to gain some appreciation of the injurious nature of bull-bars in this study but this proved not to be possible. There would be considerable merit in mounting such a study in future.

1. INTRODUCTION

Four-Wheel-Drives, Cab-Chassis Utilities and, to a lesser extent, Vans, are becoming an increasing proportion of the vehicle fleet as many people choose to drive these vehicles as an alternative to passenger cars. In 1992, sales of 4WDs and Utilities represented 18.1% of all new vehicle sales, an increase of 1.4% over the previous year (see Table 2.2).

While a number of current Australian Design Rules apply to these vehicles (such as ADR 10/01 on steering column intrusions), these vehicles are not classified as normal passenger cars or derivatives and hence are not subject to the full range of design rules that apply to passenger cars in this country.

In 1993, the Monash University Accident Research Centre was commissioned by the Federal Office of Road Safety to undertake research into vehicle occupant protection, focussing on Four-Wheel-Drive (4WD) vehicles, Vans (both passenger and light commercial) and Utilities (non-passenger car derivatives).

1.1 STUDY OBJECTIVES

The objectives of this study were to examine the extent and patterns of injuries occurring to occupants of these vehicles (including sources of injury inside and outside the vehicle) and to suggest countermeasures to reduce the frequency and severity of injury. Of particular interest was the need for more stringent safety regulations for this growing fleet of alternative passenger vehicles.

To the degree possible, the study was also to examine the consequence of having bull-bars fitted to these vehicles in terms of injuries to the vehicle occupants as well as to the occupants of vehicles struck by 4WDs, Vans and Utilities.

1.2 STUDY DESIGN

The study comprised a number of tasks as outlined below.

1.2.1 Literature Review

The first task was to undertake a review of traditional vehicle safety literature to illustrate past research and findings in this area. As the widespread use of these vehicles for the transportation of passengers is a relatively recent phenomenon, a large source of publications on the safety of these vehicles was not expected .

Literature was collected from main-stream occupant protection sources. These included international vehicle safety conference proceedings such as the International Council on the Biokinetics of Impacts (IRCOBI), The Association for the Advancement of Automotive Medicine (AAAM), the STAPP Car Conference, Enhanced Safety Vehicles (ESV), etc. Technical papers from the Society of Automotive Engineers (SAE), Transportation Research Laboratories (TRL) and the Transport Research Board (TRB) were also examined. Furthermore, literature searchers over several years were also undertaken of a number of periodicals such as Injury, the Journal of Trauma, and Accident Analysis and Prevention.

1.2.2 Mass Data Analysis

The second stage of the research program was to undertake an analysis of existing mass databases available to provide initial incidence data on injuries to occupants of 4WDs, Vans and Utilities which could then be compared with passenger car figures. The two databases which were used for this analysis were police tow-away crash records over the period January 1987 to December 1992 held by the Traffic Authority of NSW, and records of Australian fatal road crashes for the years 1988 and 1990 held by the Federal Office of Road Safety (FORS Fatal File).

1.2.3 Crashed Vehicle File

To provide more detailed information on injuries and sources of injury to occupants, inspections of crashed 4WDs, Vans and Utilities were carried out during 1993 and 1994 using the NASS format developed and refined in earlier crashed vehicle inspection programs (see FORS reports CR95 and CR134).

Given their larger mass and size, it was expected that crashes involving these vehicles (especially 4WDs) were less likely to result in hospitalisation to their occupants than passenger car crashes. Thus, revised entry criteria (from *person-based* to *vehicle-based*) were adopted for this study.

As 4WDs and Vans really started to become popular as passenger cars around 1985, a later entry criterion date (vehicles first registered 1st January 1985 or later) was also adopted. A total of 140 cases was inspected during the 1992/93 and 1993/94 financial years using these entrance criteria.

1.2.4 Project Reporting

A Project Advisory Committee, comprising members of the MTB and Research Departments of FORS as well as the Principal Investigators of the study at MUARC reviewed progress of the study during the course of the research.

This report outlines the findings of the study and makes recommendations on possible countermeasures and the need for further research.

A one-page summary of each of the crashed vehicles and occupants is found in a supplementary volume to this report.

2. LITERATURE REVIEW

2.1 DEFINITIONS

For the purpose of mass data analysis, the vehicles of interest often cannot be identified in official statistics. For example, four wheel drive vehicles (4WDs) do not appear as a separate class in the various census publications or the Australian Design Rules (ADRs). The nearest category in the ADRs is "off-road passenger vehicles", coded as MC1 and MC2. These are usually four wheel drive, but other passenger vehicles such as passenger cars may also have four wheel drive transmissions.

In the U.S. literature, four wheel drive vehicles are not identified as such. Typically, vehicles are classed as small, medium and large cars, small and standard vans, small (also compact) and standard 'pickups' and multipurpose vehicles. It is assumed that standard pickups (4500 lb (2045 kg) or more) can be regarded as similar to light goods vehicles, NA1 and NA2, in the Australian fleet. However, they are not strictly equivalent to the category of utilities which are derivatives of the 4WD class in the Australian fleet (e.g., Holden Rodeo, Toyota Hilux) as these are generally much lighter (about 1200-1600 kg). A parallelism between 'pickups' and multipurpose vehicles (sometimes multipurpose passenger vehicles) is also assumed, but this class is not homogenous.

Thus, it should be noted that the term 'pickup' is American usage and is retained throughout this literature review for lack of an Australian equivalent.

Not all the U.S. vehicles referred to have four wheel drive, though most of the multipurpose vehicles do. The percentages of vehicles with four wheel drive are: standard pickup 24%; standard van 0%; compact (ie, small) pickup 19%; minivan 0%; multipurpose vehicle 85% (Data Link, 1988).

"Forward control vans" in the literature are those in which the engine compartment and front axle are underneath (as opposed to in front of) the front passenger compartment and may be for passenger (eg, Toyota Tarago) or light commercial (e.g., Toyota Liteace) applications.

2.2 SPECIAL PURPOSE VEHICLES IN THE AUSTRALIAN FLEET

There seems no suitable category in the Australian vehicle census to which off-road-passenger vehicles can be attached, but if the light goods vehicles of the ADRs can be approximated as the light commercial vehicles of the census, their proportion of the vehicle fleet may be similar to that shown in Table 2.1.

Recent sales data for 4WDs, cab chassis utilities and vans (Table 2.2) indicate that 4WDs in particular, and utilities to a lesser extent, represent a substantial and increasing proportion of new vehicles.

Table 2.1 Proportion of Light Commercial Vehicles in the Australian Vehicle Fleet

	LCV (000s)	All Vehicles (000s)	% LCV
1976	758	6621	11.4
1979	879	7375	11.9
1982	1003	8218	12.2
1985	1140	8960	12.7
1988	1183	9418	12.6
1991	1480	10099	14.7

Source: ABS (1976-1991)

Table 2.2 New Vehicle Sales of Vans, 4WDs and Utilities

	1991	1992	% difference
Vans	15,458	14,588	-5.4%
4WDs	29,184	35,403	21.3%
Utes (cab.chas.)*	32,597	34,973	7.3%
All Vehicles**	369,464	389,330	5.4%
% 4WDs & Utes	**16.7%**	**18.1%**	**1.4%**

**Cab Chassis utilities can be supplied as either 2WD or 4WD. **Cars, Vans 4WD & c/c utes, from Paxus (1992).*

This increase in the sales of 4WDs is also reflected in the large increase (126%) in the numbers of these vehicles involved in serious casualty crashes, over an approximate five year period, as shown in Figure 2.1. Notably, crashes involving cars and motorcycles decreased by 26% and 37% respectively over the same period.

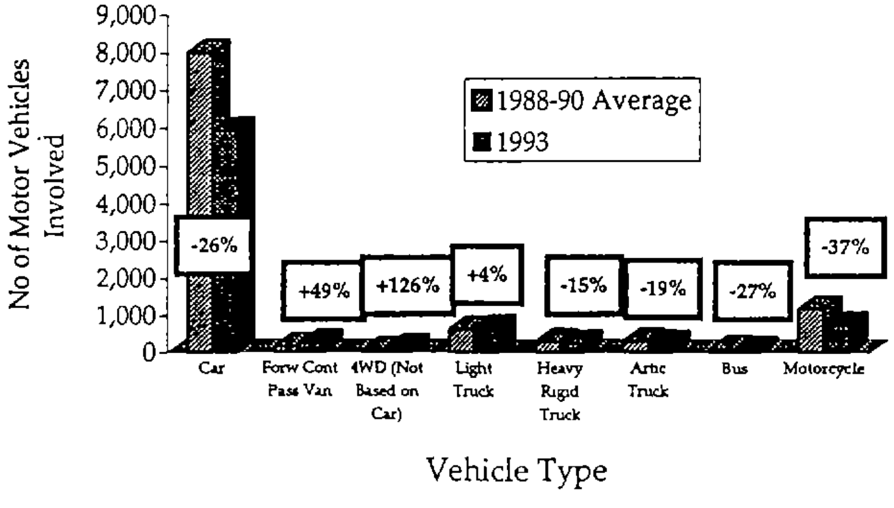


Figure 2.1 Motor vehicles involved in serious injury casualty crashes in N.S.W.

(Source: Graham and Taylor, 1994)

2.3 CRASH PERFORMANCE OF VEHICLE TYPES

Regarding overall performance, Partyka, Sikora, Surti and Van Dyne (1987) examined fatality and injury rates (per 10,000 vehicles) from the 1984 and 1985 FARS and North Carolina files, disaggregated by collision type. A combined ranking of the various vehicle types is shown in Table 2.3. Standard pickups and both small and large vans are in the middle of the range, having lower (ie, better) rankings than small and medium cars. Small pickups and multipurpose vehicles show higher rankings than the average light duty vehicle.

Table 2.3 Ranking of Injury Rates by Vehicle Type

	% (K+A)*		NORTH CAROLINA		FARS
Vehicle Type	**All Crashes**	**Towaway Crashes**	**(K+A)***	**All Injuries**	**Killed**
Small car	6	6	8	8	6
Medium car	5	5	5	7	5
Large car	3	3	4	6	1
Small van	1.5	1	1	1	3
Stand'd van	1.5	2	2	3	2
Small pickup	7	7	7	5	8
Stand'd pickup	4	4.5	3	2	4
Multi-p vehicle	8	8	6	4	7

Source: Partyka et al (1987). The ranks are standardised by vehicles on the register.
** K= killed; A= incapacitating injury.*

Table 2.4 Crashworthiness Ratings for 4WDs and Passenger Vans

			CRASHWORTHINESS RATINGS					
Make	**Model of car**	**Year of Manufact.**	**Serious Injury rate per 100 drivers involved**	**Overall rank order**	**Lower 95% confidence limit**	**Upper 95% confidence limit**	**Width of confidence interval**	**Ratio of confidence interval width to rating**
4-Wheel Driver Vehicles			**2.65**		**2.34**	**2.96**	**0.62**	**0.23**
Nissan	PATROL	82-92						
Ford	MAVERICK	88-92	1.94	16	1.15	2.73	1 58	0 82
Mitsubishi	PAJERO	83-92	2.24	27	1.22	3.27	2.05	0.91
Toyota	LANDCRUISER	82-92	2.47	37	1.84	3.10	1.27	0.51
Toyota	4RUNNER/HILUX	82-92	2.59	40	2.13	3.04	0.91	0.35
Daihatsu	ROCKY F70/75	87-92	3 53	70	1.08	5.99	4.91	1.39
Suzuki	SIERRA	82-92	3.87	76	2.62	5.12	2.50	0.65
Passenger Vans			**3.41**		**2.87**	**3.94**	**1.08**	**0.32**
Toyota	TARAGO	83-90	2.89	52	2.12	3.67	1.55	0.53
Mitsubishi	PASSENGER VANS	82-92	3.59	72	2.86	4.31	1.45	0.40

Source: Cameron, Finch & Le (1994)

2.3.1 Crashworthiness Results

Crashworthiness ratings for 1982-92 models of 4WDs and passenger vans have been developed based on crash data from NSW and Victoria over the period 1987-92 (Cameron, Finch & Lee, 1994). The crashworthiness ratings, defined as the product of severity and risk of injury, for a number of popular vehicles in Australia are shown in Table 2.4. There is some variability within the 4WD class, but their overall rating (2.65) is about the same as the all make/model average (2.66) and lower (ie, better) than that of passenger vans (3.41). It is noteworthy that the two 4WD models with high (unfavourable) ratings are vehicles of relatively low mass. Similar, but rather older rating on US vehicles (Highway Loss Data Institute, 1988) indicate that "among vans, pickups and utility vehicles, large and small utility vehicles and small pickups are the worst. Injury claim figures were closely related to vehicle size, with the larger vehicles having lower claim frequencies." Within each class, there was considerable variability (4WDs, though, did not differ appreciably from 2WD vehicles).

2.3.2 Crash Test Results

Full frontal tests conducted on vehicles on the Australian market under the New Car Assessment Program (NCAP, 1994) include five 4WDs and four passenger vans. These tests are carried out at an impact velocity of 56 km/h. A further test series of six 4WDs, conducted by the same testing organisation but at 48 km/h, have been reported by Higgins and Seyer (1995). The main results of the two series are shown in Table 2.5.

In the two series, the chest compression and femur loads are within the limits prescribed by Australian Design Rule 60/00. The chest acceleration exceeded the limit in two vehicles of the NCAP series and in one of these, for the driver, in the 48 km/h series. Three vehicle models are common to both test series. The measured values are not systematically different despite the difference in impact velocities.

In the 48 km/h series, the HICs were all within the limit except for the driver in one model and the passenger in another, the latter being due to the dummy's head striking the thigh. All the driver HICs and two passenger HICs exceeded 1000 in the NCAP series.

In the NCAP passenger van full frontal tests, all chest compressions and all femur loads but one were within the ADR limits. Four of eight chest accelerations exceeded 60g and all HICs exceeded the limit value.

Table 2.5 Crash Test Results

Impact velocity	NCAP Tests 56 km/h					FORS Tests 48 km/h				
	HIC	chest		femur		HIC	chest		femur	
		comp	acc	L	R		comp	acc	L	R
Land Rover Discovery										
driver	1530.0	46	54	1.9	3.2					
passenger	760.0	31	47	3.0	1.4					
Mitsubishi Pajero										
driver	1880.0	41	49	2.8	1.0	1167.1	53.9	46.2	0.8	0.7
passenger	790.0	43	49	0.9	0.4	628.3	43.7	48.2	0.7	1.3
Suzuki Vitara										
driver	1240.0	52	84	7.1	6.2	945.1	57.4	69.3	5.2	1.8
passenger	1810.0	40	72	1.1	1.1	1379.0	45.7	54.2	0.6	0.6
Toyota Landcruiser										
driver	1140.0	47	48	7.5	2.5	773.8	44.4	43.1	3.0	2.8
passenger	700.0	37	40	1.4	3.2	573.2	33.7	37.4	2.3	3.8
Nissan Patrol										
driver	1750.0	44	67	2.8	2.0					
passenger	1840.0	41	59	1.3	3.3					
Holden Rodeo										
driver						708.9	42.0	48.5	0.2	0.4
passenger						612.8	39.7	43.0	0.7	0.6
Mitsubishi Triton										
driver						791.4	39.3	42.5	0.8	0.9
passenger						471.4	38.5	40.1	1.1	0.6
Toyota Hilux										
driver						881.1	43.5	51.0	0.7	3.0
passenger						589.0	33.3	46.3	1.4	1.9
ADR69/00	1000	76.2	60	10		1000	76.2	60.0	10	

Sources: NCAP 1994, Higgins & Seyer, 1995 (FORS)
Chest = chest compression. mm; acceleration. g; femur = compressive load, kN
All vehicles manufactured between January and May, 1994

2.4 ROLLOVERS

Rollovers are worthy of special mention because of their generally more injurious outcomes than other crash modes. The rollover experience of various vehicle types in the USA is illustrated in Figure 2.2. Because of the high centre of gravity relative to wheel base, pickups and 4WDs would be expected to have an increased propensity to rollover (eg, Mengert, Salvatore, DiSario & Walter, 1989). Increased propensity to rollover has been shown to characterise small "jeep-like" utility vehicles (Reinfurt, Stutts & Hamilton, 1984). Rollover propensity is likely to exist in 4WD vehicles in the Australian fleet which do not have the configuration of passenger cars. Vans in general do not appear to share this propensity to rollover, although Rattenbury and Gloyns (1990) reported an increased propensity for forward control vans to be involved in rollover crashes.

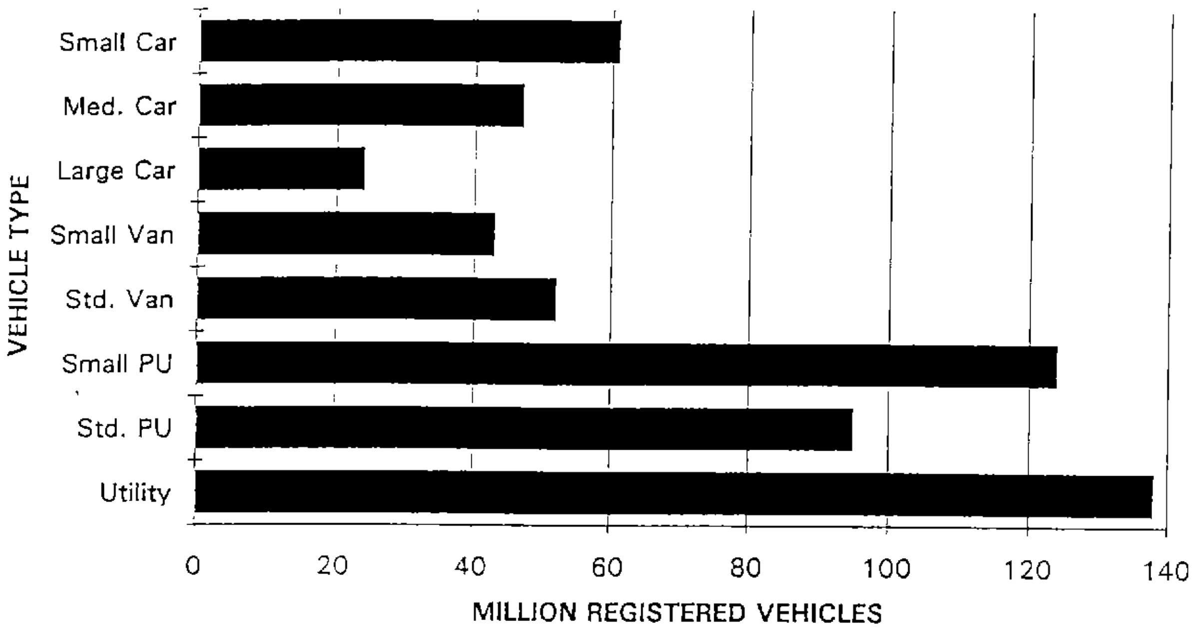


Figure 2.2 Relative rollover fatality rate per million registered vehicles
(Source. Hinch, Shadle & Klein (1992), based on US data, 1985-89)

What appears to be the final word on the propensity of individual vehicle types to overturn is provided by Klein (1994) who repeated the type of analysis used by Mengert, but made use of logistic regression. The data came from the (US) National Accident Sampling System (NASS) for five states over several years in the late 1980's.

Tilt ratio was found to be the best predictor of rollover propensity. The vehicle classes, Sport Utility, Van, and Pickup, were significantly more likely to rollover than passenger cars, the reference class. Front wheel drive vehicles were more significantly likely to rollover than rear wheel drive vehicles. These results are independent of variables such as driver age, type of road and alcohol use.

2.5 SPECIFIC INJURY TYPES

2.5.1 'Pickup Trucks'

Occupant injuries in pickup trucks have been analysed from records of nearly 1400 collisions collected by multi-disciplinary teams in Canada between 1981 and 1984 (Cunningham & Wilson, 1989). Drivers had a higher incidence of serious or fatal injury than front seat passengers, attributed to the steering wheel and foot controls. These results are not that dissimilar to those of passenger cars.

Restrained front occupants had fewer and less severe injuries than those unrestrained in the same seating positions in frontal collisions, side impacts (including those with compartment intrusion) and rollovers. Events resulting in intrusion, ejection and rollover exposed front occupants to greater risk of severe and multiple injury than the generality of accidents. The relation of injury level to impact speed is illustrated in Figure 2.4 for unrestrained and restrained front occupants respectively.

In rear end collisions, according to Cunningham and Wilson (1989), the occupants of pick-up trucks benefited from increased energy absorption capability provided by the cargo space, but integral head restraints were advocated. Other improvements suggested were strengthening of the vehicle's upper body structure components. A particular feature of pickup accidents is the susceptibility of these vehicles to injury of occupants riding in the rear "tray", "bed" or cargo space (Hamar, King, Bolton & Fine, 1991; Bucklew, Osler, Eidson, Clavenger, Olson & Demarest, 1992; Nelson & Struebert, 1991). Children appear to be especially at risk (Agran, Winn & Castillo, 1990; Tong & Teaford, 1989; Woodward & Bolte, 1990).

2.5.2 Forward Control Vans

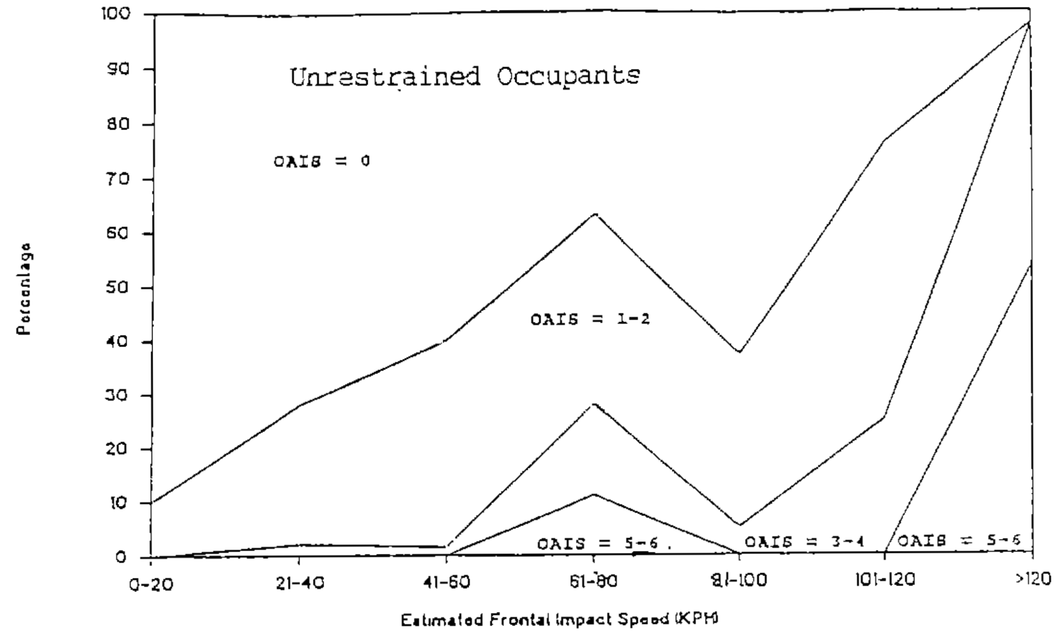
Forward control vans, which do not have a bonnet, fail to provide protection to front seat passengers equivalent to that provided in passenger cars. Davis (1986) found, in NSW, that the rate of injury accidents among forward control vans was 27% higher than that of cars. In a crashed vehicle study, injuries to front seat passengers were caused by the dashboard, steering wheel, and, most commonly, were to the legs. The steering wheel displacement permitted by ADR 10B was considered to be too large to prevent driver injury in these vehicles.

Barrier tests were carried out on representative forward control vans manufactured between 1981 and 1985 (Federal Office of Road Safety, 1986). Gross vehicle mass ranged from 1350 to 2395 kg. The main observations from these tests were the substantial rearward movement of the steering wheel and reduction of footroom in most of the tests. Representative illustrations of good and poor performers are shown in Figures 2.5 and 2.6.

Application of rules such as ADR10B or ECE Regulation 33 would have a significant improvement in the "*survival space*" of these vehicles, though neither rule in existing form was entirely suitable for the forward control configuration.

Forward control van crash performance was investigated by Paix, Gibson and McLean (1985) using data from the Victorian Motor Accidents Board and from a sample of towaway crashes in Adelaide. The MAB data showed that front seat occupants of forward control vans not only had a different pattern of injuries than occupants of passenger cars but also that the overall severity of injuries was greater in terms of treatment costs (see Figure 2.6). In frontal impacts forward control van occupants had proportionately more leg injuries and fewer head and chest injuries than car occupants.

The towaway crash series confirmed the excess of leg injuries in forward control vans and showed a high incidence of intrusion in vehicles with front end damage. Intrusion involved components mounted in the dashboard area, such as brake master cylinders and booster, air-conditioner and heater assemblies.



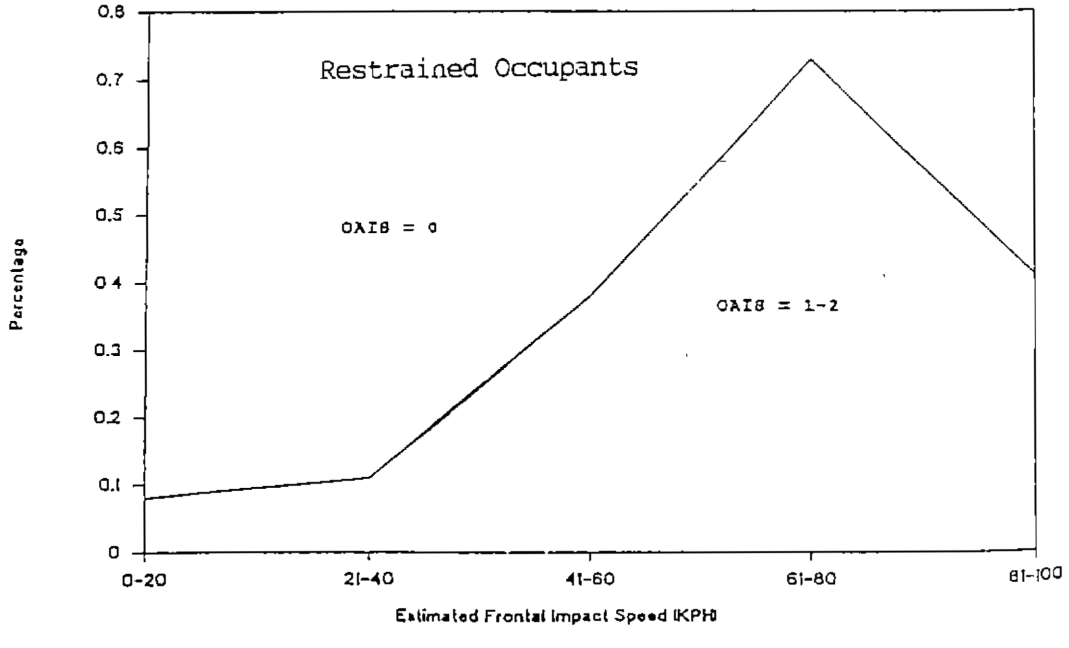


Figure 2.3 Overall Abbreviated Injury Scale (OAIS) for unrestrained and restrained front occupants injured in pick-up crashes in Canada by estimated impact speed

(Source: Cunningham & Wilson (1989).

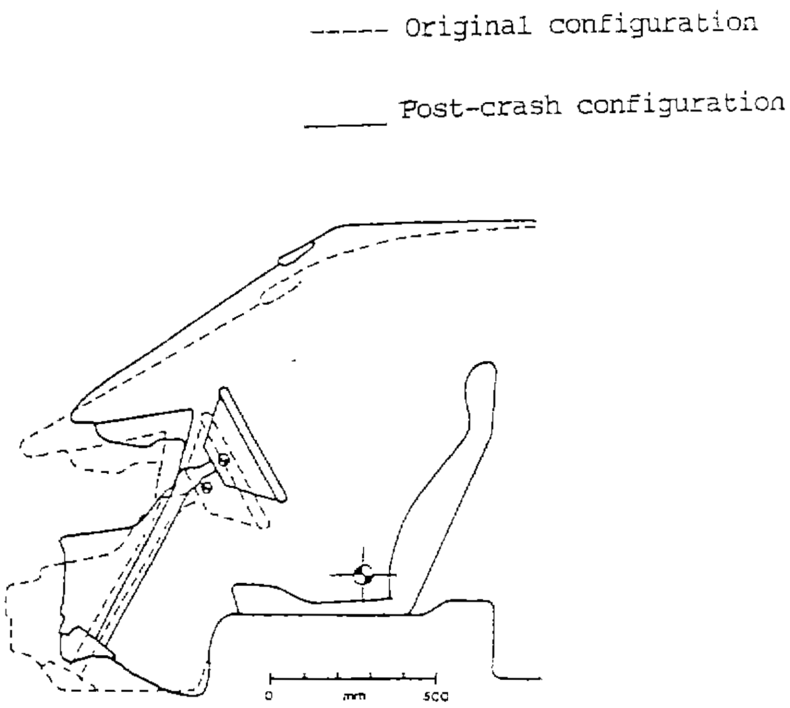


Figure 2.4 Outline of a good performing forward control van in the series of barrier crash tests

(Source: Federal Office of Road Safety 1986)

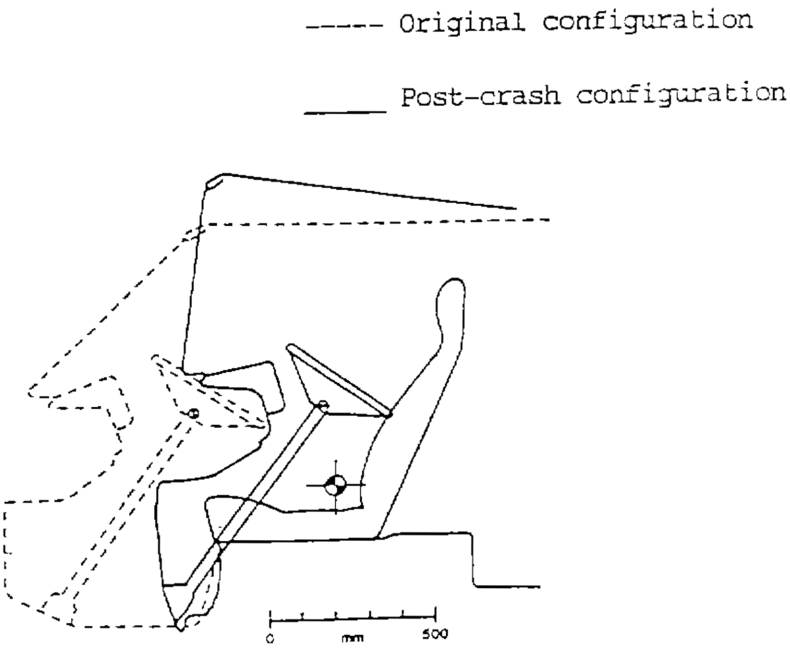


Figure 2.5 Outline of a poor performing forward control van in the series of barrier crash tests

(Source: Federal Office of Road Safety 1986)

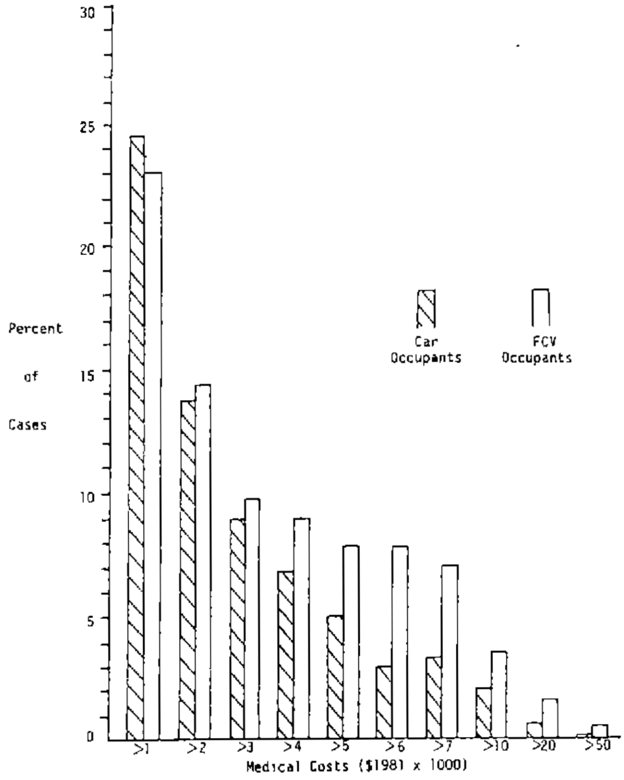


Figure 2.6 Medical costs for front seat occupants of forward control vans and passenger cars, all crashes.

(Source: Paix et al, 1985)

2.6 CONCLUSIONS

The literature on 4WDs, Vans and 'pickup trucks' is scanty and not easy to interpret in terms of its relevance to the vehicle types in the Australian vehicle fleet which are the focus of the current study.

Mass data results in the US indicate that the classes "sports utility, van and pick-up" were more likely to rollover than were passenger cars.

Australian data suggested that 4WD vehicles have a crash performance as good as that of passenger cars generally, but not necessarily superior. While direct evidence is lacking, the small 4WD utility vehicles are likely to have an increased tendency to overturn.

Forward control vans, on the other hand, show evidence of more severe injury to front seat occupants compared with front seat occupants in conventional passenger cars. Leg injuries are a feature of crashes to forward control vans.

On overseas evidence, 'pickup trucks' appear to provide less protection than the generality of vehicles although this is somewhat dependent on the type of crash. Occupants of the rear tray or cargo space in pickups are particularly at risk of injury and severe injury.

3. MASS DATABASE ANALYSIS

3.1 DATABASES

Two databases were sourced for the mass data analysis. The Roads and Traffic Authority of N.S.W. maintain the database of police-reported crashes in that state while the Federal Office of Road Safety (FORS) hold the national fatal file for all fatal road crashes in Australia. Both these databases contain codes on special purpose vehicles such as 4WD, vans and utilities of interest in this study. The Transport Accident Commission injury compensation database and the VicRoads database on police-reported casualty crashes in the state of Victoria did not contain the specific codes for vehicle types needed for this mass data analysis.

The N.S.W. database contains six years of data (1987-1992) of police-reported crashes in the state of N.S.W. Entrance into this database is dependent on at least one person involved in the crash being injured or at least one of the vehicles being towed away from the crash scene. Variables of interest from this database were vehicle type, impact direction, speed zone and injury outcome.

The FORS Fatal File is compiled biannually and contains details on all fatal road accidents occurring throughout Australia. The 1988 and 1990 files were sourced for this analysis, and in most cases the results are based on the combined data for both years (although for some variables, only 1990 data were available).

3.1.1 Variables and Analyses

The major independent variable for the analyses was vehicle type, focussing on the three special purpose categories relevant to this study (4WDs, Vans and Utilities) and a fourth category of passenger cars. Other independent variables of interest included crash type (or primary impact direction), speed zone, seating position and occupant characteristics such as age and sex. The existence of a bull-bar (although of potential interest) could not be included as an independent variable because this information was not consistently coded in either of the databases.

The major dependent variables were indices of injury outcome such as casualty level (fatal, hospitalised or medically treated) (N.S.W. and FORS files), injury severity (ISS) and body regions injured (location of most severe injury and final cause of death) (FORS fatal file only). Other dependent variables investigated from the FORS fatal file were ejection and entrapment.

Each of the databases was analysed using the Statistical Package for the Social Sciences (SPSS).

3.2 N.S.W. CASUALTY DATA

All analyses of the NSW database were based on the subset of casualty crashes (ie, where at least one occupant was injured). Injury outcome results are presented for front seat occupants only as the number of rear occupants was very small. The category of 'nose-tail' crashes included in the crash type by vehicle type analysis was modified for the analysis of injury outcomes by crash types to include the impacted vehicle only; this enabled an examination of the effects of being impacted from the rear on injury outcome.

3.2.1 Overview of Data

Table 3.1 shows the frequency distributions of several relevant crash, vehicle and occupant variables. Four wheel drive vehicles were over-involved in casualty crashes occurring in speed zones of 75 km/h or more (usually rural roads) compared with passenger cars, vans and utilities. To some degree, this probably reflects differences in exposure of these vehicle types in different road environments, as passenger cars would be expected to predominate in urban areas with lower speed limits, and 4WDs to be more prevalent in rural areas with higher speed limits.

By comparison with passenger cars, injured drivers of 4WDs, vans and utilities were more likely to be male and aged 26-55 years, probably reflecting exposure differences.

3.2.2 Crash Types

The type of impact in casualty crashes for the vehicle types of interest in the NSW data is shown in Table 3.2. By comparison with the other vehicle types, 4WDs were considerably over-involved in rollover casualty crashes, consistent with their over-use in rural areas, although vans and utilities had a higher involvement in rollovers than did passenger cars.

Although the literature does not contain much evidence on 4WDs of the type investigated in this study, it did suggest that vehicles with a high centre of gravity (eg, American "pick-ups" and "jeep-like" utilities) had an increased propensity to rollover (eg; Mengert et al, 1989).

An analysis of impact type by speed zone (see Table 3.3) for all tow-away crashes (i.e., casualty and non-casualty) shows that rollover crashes are 12 times more likely in high speed zones by comparison with low speed zones. Over-involvement in high speed zones, albeit to a much lesser degree, was also apparent for head-ons (3:1) and single-vehicle crashes (approx. 4:1). In rollover crashes (Table 3.4), it is noteworthy that 4WD vehicles are two times more likely than passenger cars and one and a half times more likely than utilities to be involved in high-speed-zone rollovers. Notably, 4WDs also have an increased likelihood of rollover in low speed zones by comparison with the other vehicle types. This suggests that the propensity of 4WDs to rollover in low speed zone crashes is greater than for other vehicle types in equivalent crashes.

3.2.3 Injury Outcome

The NSW database does not code for type of injury or injury severity, so only injury outcome could be compared across the different vehicle types. Injury outcome is defined as whether the occupant(s) were killed, hospitalised, received medical treatment or were uninjured.

Table 3.5. shows that front-seat occupants of 4WDs have a considerably greater chance of being killed and a somewhat greater chance of being hospitalised, than occupants of other vehicle types. While this is probably influenced to some degree by the higher involvement of 4WDs in rural crashes and rollovers, it does suggest, however, that these vehicles may not be as safe as is generally considered among the population at large.

In general, serious injury outcomes (killed or hospitalised) were more frequent in head-on, single vehicle and rollover crashes (in that order) and at high (≥ 75 km/h) rather than low (<75 km/h) speeds.

Further analyses of injury outcome by vehicle type was conducted, controlling for crash type and speed zone (Tables 3.6 to 3.15).

Table 3.1 Characteristics of the NSW Database for Casualty Crashes Occurring between 1987 and 1992

	Passenger Car		Passenger Van		Four Wheel Drive		Light Truck/Utility	
	Freq	**(%)**	**Freq**	**(%)**	**Freq**	**(%)**	**Freq**	**(%)**
Speed Zone:								
Less than 75 km/h	132822	(80)	3115	(75)	904	(62)	9258	(74)
75 km/h or more	32739	(20)	1033	(25)	552	(38)	3242	(26)
Age of Driver:								
Less than 25 years	56132	(35)	881	(22)	431	(31)	3503	(30)
25-55 years	82648	(51)	2769	(69)	859	(61)	7313	(62)
56 years or more	22025	(14)	389	(9)	122	(8)	1013	(8)
Sex of Driver:								
Male	103333	(64)	3025	(74)	1092	(76)	10567	(88)
Female	58919	(36)	1051	(26)	336	(24)	1389	(12)
BAC of Driver:								
0.05 or less	66469	(47)	1569	(46)	609	(49)	5444	(52)
More than 0.05	2831	(2)	58	(2)	33	(3)	242	(2)
Not tested	70851	(51)	1781	(52)	604	(48)	4772	(46)

Source: NSW Crash Database 1987-1992

Table 3.2 Number of Crashed Vehicles by Vehicle Type and Impact Direction

	Impact Direction					
Vehicle Type	**Head On (%)**	**Rollover (%)**	**Side Impact (%)**	**Nose-tail (%)**	**Single Vehicle (%)**	**Other (%)**
Passenger Car	14517	5366	39222	34520	20669	55611
(n=169905)	(9)	(3)	(23)	(20)	(12)	(33)
Passenger Van	445	272	893	752	485	1405
(n=4252)	(10)	(6)	(21)	(18)	(11)	(33)
Four Wheel Drive	208	178	266	289	214	359
(n=1514)	(14)	(12)	(18)	(19)	(14)	(24)
Light Truck/Utility	1318	757	2460	2532	1390	4381
(n=12838)	(10)	(6)	(19)	(20)	(11)	(34)
Total	16488	6573	42841	38093	22758	61756
(n=188509)	(9)	(3)	(23)	(20)	(12)	(33)

Source: NSW Crash Database 1987-1992

Table 3.3 Number of Crashed Vehicles by Speed Zone and Impact Direction

	Impact Direction					
Speed Zone	**Head On (%)**	**Rollover (%)**	**Side Impact (%)**	**Nose-tail (%)**	**Single Vehicle (%)**	**Other (%)**
Low (<75 km/h) (n=142984))	19885 (5)	4119 (1)	118172 (27)	116848 (26)	31524 (7)	151699 (34)
High (≥75 km/h) (n=36533)	11267 (13)	9912 (12)	6411 (8)	22073 (26)	22335 (26)	13737 (16)
Ratio High/Low	***3***	***12***	***0.3***	***1***	***4***	***0.5***

Source: NSW Crash Database 1987-1992

Table 3.4 Number of Crashed Vehicles in Rollovers by Vehicle Type and Speed Zone

	Vehicle Type		
Speed Zone	**Passenger Car (%)**	**4WD (%)**	**Light Truck (%)**
Low (<75 km/h) (n=142984))	3688 (1)	73 (3)	378 (2)
High (≥75 km/h) (n=36533)	8600 (11)	234 (23)	1078 (16)
Ratio High/Low	***11***	***8***	***8***

Source: NSW Crash Database 1987-1992

Table 3.5 Injury Outcome by Vehicle Type for Front Seat Occupants, *All* Crashes

	Injury Outcome			
Vehicle Type	**Fatality (%)**	**Hospitalised (%)**	**MedicallyTreated (%)**	**Nontreated Injury (%)**
Passenger Car (n=101972)	2175 (2)	20631 (20)	72143 (71)	7023 (7)
Passenger Van (n=2587)	62 (2)	597 (23)	1769 (68)	159 (6)
Four Wheel Drive (n=883)	54 (6)	236 (27)	502 (57)	91 (10)
Light Truck/Utility (n=6222)	191 (3)	1506 (24)	4084 (66)	441 (7)
Total (n=111664)	2482 (2)	22970 (21)	78498 (70)	7714 (7)

Source: NSW Crash Database 1987-1992

ROLLOVERS: Tables 3.6 and 3.7 show the Injury Outcome for occupants of all vehicle types in rollover crashes. In rollover crashes in both high and low speed zones, occupants of 4WDs were more likely to be killed by comparison with occupants of vans or passenger cars. Moreover, in low speed zones, they were more likely to be hospitalised as well.

This finding is noteworthy given that 4WDs appear to have a propensity to rollover and that rollover crash configurations are generally associated with more severe injuries than other crash modes (Fildes, Lane, Lenard & Vulcan, 1991; Rechnitzer & Lane, 1994).

Occupants of utilities also had a relatively high incidence of injuries requiring hospitalisation in high speed rollover crashes but a relatively low incidence of such injuries in low speed rollover crashes. Overall, the number of front-seat casualties in rollover crashes was four times higher at speeds greater than 75km/h than at speeds less than 75 km/h (5962 cf. 1460). Thus, while high speed rollovers represent 70% of all tow-away rollover crashes (from Table 3.3), they account for 80% of rollover injuries.

SINGLE VEHICLE CRASHES: Four-wheel-drive occupants were over-involved in a fatal outcome in high speed zone crashes, as shown in Table 3.8. Moreover, those in 4WDs and utilities were also slightly over-involved in a hospitalised outcome in these high speed zone crashes by comparison with the other vehicle types. This probably reflects greater usage of these vehicles in rural areas where speed limits are generally higher.

Vehicle type, however, seemed to have had very little influence on the injury outcome for occupants of single vehicle crashes in low speed zones (Table 3.9).

Table 3.6 Injury Outcome by Vehicle Type for Front Seat Occupants in *Rollover* Crashes in *High* Speed Zones

	Injury Outcome			
Vehicle Type	**Fatality (%)**	**Hospitalised (%)**	**MedicallyTreated (%)**	**Nontreated Injury (%)**
Passenger Car	127	1403	2956	320
(n=4806)	(3)	(29)	(61)	(7)
Passenger Van	3	70	173	12
(n=258)	(1)	(27)	(67)	(5)
Four Wheel Drive	16	50	98	16
(n=180)	(9)	(28)	(54)	(9)
Light Truck/Utility	22	268	385	43
(n=718)	(3)	(37)	(54)	(6)
Total	168	1791	3612	391
(n=5962)	(3)	(30)	(60)	(7)

Source: NSW Crash Database 1987-1992

Table 3.7 Injury Outcome by Vehicle Type for Front Seat Occupants in *Rollover* Crashes in *Low* Speed Zones

	Injury Outcome			
Vehicle Type	**Fatality (%)**	**Hospitalised (%)**	**MedicallyTreated (%)**	**Nontreated Injury (%)**
Passenger Car	20	226	834	93
(n=1173)	(2)	(19)	(71)	(8)
Passenger Van	0	13	45	5
(n=63)	(0)	(21)	(71)	(8)
Four Wheel Drive	3	10	23	4
(n=40)	(8)	(25)	(57)	(10)
Light Truck/Utility	5	28	139	12
(n=184)	(3)	(15)	(76)	(6)
Total	28	277	1041	114
(n=1460)	(2)	(19)	(71)	(8)

Source: NSW Crash Database 1987-1992

Table 3.8 Injury Outcome by Vehicle Type for Front Seat Occupants in *Single Vehicle* Crashes in *High* Speed Zones

	Injury Outcome			
Vehicle Type	**Fatality (%)**	**Hospitalised (%)**	**MedicallyTreated (%)**	**Nontreated Injury (%)**
Passenger Car	473	3600	6460	616
(n=11149)	(4)	(32)	(58)	(6)
Passenger Van	12	96	176	13
(n=297)	(4)	(32)	(59)	(4)
Four Wheel Drive	18	60	71	18
(n=167)	(11)	(36)	(42)	(11)
Light Truck/Utility	64	303	449	49
(n=865)	(7)	(35)	(52)	(6)
Total	567	4059	7156	696
(n=12478)	(5)	(32)	(57)	(6)

Source: NSW Crash Database 1987-1992

Table 3.9 Injury Outcome by Vehicle Type for Front Seat Occupants in *Single Vehicle* Crashes in *Low* Speed Zones

	Injury Outcome			
Vehicle Type	**Fatality (%)**	**Hospitalised (%)**	**MedicallyTreated (%)**	**Nontreated Injury (%)**
Passenger Car	294	3261	7643	502
(n=11700)	(3)	(28)	(65)	(4)
Passenger Van	5	70	150	10
(n=235)	(2)	(30)	(64)	(4)
Four Wheel Drive	1	22	50	5
(n=78)	(1)	(28)	(64)	(6)
Light Truck/Utility	16	161	419	40
(n=636)	(3)	(25)	(66)	(6)
Total	316	3514	8262	557
(n=12649)	(3)	(28)	(65)	(4)

Source: NSW Crash Database 1987-1992

HEAD-ON CRASHES: In high speed zone head-on crashes (i.e., 75 km/h or greater) there were more fatalities and hospitalisations than for head-on crashes in low speed zones, but there were no real differences in injury outcome across the vehicle types (Table 3.10).

For low speed zone head-on crashes (i.e., less than 75 km/h), vans appeared to be slightly over-represented in numbers of fatalities, but there were no other apparent differences in injury outcome across the vehicle types (Table 3.11).

SIDE IMPACT CRASHES: Four-wheel-drives, and to a lesser extent, vans and utilities, are under-represented in injury outcomes from side impact crashes in high speed zones by contrast with passenger cars, making comparisons between the vehicle types meaningless (Table 3.12). Injury outcomes from side impact crashes in low speed zones showed no obvious differences between the four vehicle types (Table 3.13).

REAR END CRASHES: The relative safety for occupants involved in rear-end crashes by comparison with other crash types is evidenced by an increase in the number of those uninjured or only requiring medical treatment, compared to other crash types and the fewer number of fatalities (Tables 3.14 & 3.15). The increase in safety of rear-end crashes has been alluded to earlier in other mass data analyses (Fildes et al, 1991).

Table 3.10 Injury Outcome by Vehicle Type for Front Seat Occupants in *Head-On* Crashes in *High* Speed Zones

	Injury Outcome			
Vehicle Type	**Fatality (%)**	**Hospitalised (%)**	**MedicallyTreated (%)**	**Nontreated Injury (%)**
Passenger Car	646	2286	2664	159
(n=5755)	(11)	(40)	(46)	(3)
Passenger Van	21	83	101	6
(n=211)	(10)	(39)	(48)	(3)
Four Wheel Drive	9	30	39	6
(n=84)	(11)	(36)	(46)	(7)
Light Truck/Utility	42	158	198	19
(n=417)	(10)	(38)	(47)	(5)
Total	718	2557	3002	190
(n=6467)	(11)	(40)	(46)	(3)

Source: NSW Crash Database 1987-1992

Table 3.11 Injury Outcome by Vehicle Type for Front Seat Occupants in *Head-On* Crashes in *Low* Speed Zones

	Injury Outcome			
Vehicle Type	**Fatality (%)**	**Hospitalised (%)**	**MedicallyTreated (%)**	**Nontreated Injury (%)**
Passenger Car	184	1567	3877	233
(n=5861)	(3)	(27)	(66)	(4)
Passenger Van	9	44	90	9
(n=152)	(6)	(29)	(59)	(6)
Four Wheel Drive	1	13	26	4
(n=44)	(2)	(30)	(59)	(9)
Light Truck/Utility	9	101	238	14
(n=362)	(2)	(28)	(66)	(4)
Total	203	1725	4231	260
(n=6419)	(3)	(27)	(66)	(4)

Source: NSW Crash Database 1987-1992

Table 3.12 Injury Outcome by Vehicle Type for Front Seat Occupants in *Side Impact* Crashes in *High* Speed Zones

	Injury Outcome			
Vehicle Type	Fatality (%)	Hospitalised (%)	MedicallyTreated (%)	Nontreated Injury (%)
Passenger Car	46	495	1417	83
(n=2041)	(2)	(24)	(70)	(4)
Passenger Van	0	10	33	0
(n=43)	(0)	(23)	(77)	0
Four Wheel Drive	1	3	7	3
(n=14)	(7)	(21)	(50)	(21)
Light Truck/Utility	2	31	64	8
(n=105)	(2)	(29)	(61)	(8)
Total	49	539	1521	94
(n=2203)	(2)	(25)	(69)	(4)

Source: NSW Crash Database 1987-1992

Table 3.13 Injury Outcome by Vehicle Type for Front Seat Occupants in *Side Impact* Crashes in *Low* Speed Zones

	Injury Outcome			
Vehicle Type	Fatality (%)	Hospitalised (%)	MedicallyTreated (%)	Nontreated Injury (%)
Passenger Car	140	2788	16091	1318
(n=20337)	(1)	(14)	(79)	(6)
Passenger Van	3	65	378	34
(n=480)	(1)	(13)	(79)	(7)
Four Wheel Drive	1	11	52	8
(n=72)	(1)	(15)	(72)	(11)
Light Truck/Utility	4	131	727	62
(n=924)	0	(14)	(79)	(7)
Total	148	2995	17248	1422
(n=21813)	(1)	(14)	(79)	(6)

Source: NSW Crash Database 1987-1992

Table 3.14 Injury Outcome by Vehicle Type for Front Seat Occupants in *Rear End* Crashes (Impacted Vehicle Only) in *High* Speed Zones

	Injury Outcome			
Vehicle Type	**Fatality (%)**	**Hospitalised (%)**	**MedicallyTreated (%)**	**Nontreated Injury (%)**
Passenger Car	16	191	1371	216
(n=1794)	(1)	(11)	(76)	(12)
Passenger Van	0	5	19	7
(n=31)	0	(16)	(61)	(23)
Four Wheel Drive	1	4	15	4
(n=24)	(4)	(17)	(62)	(17)
Light Truck/Utility	2	24	114	14
(n=154)	(1)	(16)	(74)	(9)
Total	19	224	1519	241
(n=2003)	(1)	(11)	(76)	(12)

Source: NSW Crash Database 1987-1992

Table 3.15 Injury Outcome by Vehicle Type for Front Seat Occupants in *Rear End* Crashes (Impacted Vehicle Only) in *Low* Speed Zones

	Injury Outcome			
Vehicle Type	**Fatality (%)**	**Hospitalised (%)**	**MedicallyTreated (%)**	**Nontreated Injury (%)**
Passenger Car	9	461	7047	1366
(n=8883)	(0)	(5)	(79)	(15)
Passenger Van	0	9	112	13
(n=134)	(0)	(7)	(83)	(10)
Four Wheel Drive	0	1	23	6
(n=30)	(0)	(3)	(77)	(20)
Light Truck/Utility	0	21	249	51
(n=321)	(0)	(6)	(78)	(16)
Total	9	492	7431	1436
(n=9368)	(0)	(5)	(79)	(15)

Source: NSW Crash Database 1987-1992

3.3 FORS FATALITY FILE

While the FORS fatal file includes a category known as 'Light Commercial', this did not equate to the category of 'Utilities' used in the crashed vehicle file in the current study, as it also contains vans other than passenger vans and rigid trucks of not more than 3.5 tonnes. In addition, while the 'Van' category in the crashed vehicle file contained both passenger and light commercial vans, the FORS fatal file only distinguishes 'Passenger Vans' as a separate class. Thus, comparisons between vehicle types in the FORS fatal file were confined to 4WDs, Passenger Vans and Passenger Cars.

3.3.1 Overview of Data

Table 3.16 shows the frequency distributions of several relevant crash and occupant variables for three vehicle categories of interest. By comparison with passenger cars and vans, 4WDs were over-represented in fatal crashes that occurred on unsealed roads, in high speed zones (≥75 km/h), and in rollover crashes. Of special interest, the majority of 4WD fatal crashes have rollover as their primary impact (54%) and in a further 11% of cases, the vehicle subsequently rolled over after the primary impact.

These figures were considerably higher than for either passenger cars or vans and confirm the findings from the previous analysis that occupants of 4WD vehicles experience severe injury outcomes, probably because of higher impact speeds from rural crashes and the inherent instability of the vehicle. The majority of drivers of 4WDs involved in fatal crashes also tended to be in the 26-55 year age group, whereas drivers of passenger cars killed tended to be younger (<26 years). Apart from a slight preponderance of male van drivers, there was no marked differences in the sex distribution of drivers in fatal crashes across the three vehicle types. Drivers of 4WDs involved in fatal crashes were slightly more likely to have an illegal BAC (>.05) than other drivers.

Table 3.16 Characteristics of the FORS Database for Fatal Crashes Occurring in 1989 and 1990

	Passenger Car		Passenger Van		Four Wheel Drive	
	Freq	(%)	Freq	(%)	Freq	(%)
Road Surface:						
Sealed	2405	(94)	84	(92)	82	(85)
Unsealed	158	(6)	7	(8)	14	(15)
Speed Zone:						
Less than 75 km/h	782	(31)	25	(28)	13	(14)
75 km/h or more	1745	(69)	64	(72)	79	(86)
Primary Impact:						
Frontal	1094	(44)	53	(60)	25	(27)
Side	817	(33)	14	(16)	12	(13)
Rollover	499	(20)	20	(22)	50	(54)
Other	96	(4)	2	(2)	5	(5)
Age of Driver:						
Less than 25 years	989	(39)	29	(33)	29	(31)
26-55 years	1050	(41)	47	(53)	52	(56)
56 years or more	493	(19)	13	(15)	12	(13)
Sex of Driver:						
Male	1896	(74)	74	(82)	72	(77)
Female	651	(26)	16	(18)	22	(23)
BAC of Driver:						
0.05 or less	1137	(49)	47	(56)	36	(45)
More than 0.05	684	(29)	18	(21)	26	(33)
Not tested	501	(22)	19	(23)	18	(23)

Source: 1988 & 1990 FORS Fatality Files

Table 3.17 Injury Outcome and Injury Severity Scores (ISS) for Occupants of Vehicles Involved in Fatal Crashes by Vehicle Type

	Passenger Car		Passenger Van		Four Wheel Drive	
	Freq	**(%)**	**Freq**	**(%)**	**Freq**	**(%)**
Degree of Casualty						
Not Injured	1785	(25)	123	(33)	109	(28)
Inj, No Med Trtmt	131	(2)	3	(1)	16	(4)
Inj, Med Trtmt	815	(11)	48	(13)	56	(15)
Hospitalised	1766	(25)	110	(29)	98	(25)
Died	2588	(36)	91	(24)	98	(25)
Unknown	95	(1)	2	(1)	8	(2)
Total	**7180**	**(100)**	**377**	**(100)**	**385**	**(100)**

	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)
ISS:						
All Occupants	40	(21)	35	(18)	37	(22)
Drivers	41	(21)	33	(17)	37	(20)

Source: 1988 & 1990 FORS Fatality Files

3.3.2 Injury Outcome

The overall injury outcome for occupants of vehicles involved in fatal crashes is shown in Table 3.17 by vehicle type. Occupants of passenger cars appeared to suffer the worst outcome, with 36% of them dying as a result of a fatal crash (cf. 25% and 24% for 4WDs and vans respectively). For drivers only, there was little difference in injury outcome across vehicle types - roughly 60-70% of drivers died in fatal crashes and a further 19% were hospitalised.

3.3.3 Injury Severity Score (ISS)

The Fatal File has the capacity for scoring up to 10 injuries per injured occupant. All injuries are scored in terms of the Abbreviated Injury Scale (AIS 85) including their severity in terms of the likelihood of death. The Injury Severity Score (ISS) is the sum of the squares of the three highest AIS scores and is a generally accepted measure of total injury severity.

Table 3.17 shows that there was considerable variation in the mean ISS scores for occupants of the three vehicle types, with occupants of passenger cars recording the highest ISS scores in fatal crashes. However, the high standard deviations for all vehicle types indicate substantial variation in ISS scores across vehicle category which suggests these results need to be interpreted with considerable caution.

Table 3.18 Final Cause of Death and Location of Most Severe Injury by Vehicle Type for Occupants Killed in All Crashes

	Passenger Car		**Passenger Van**		**Four Wheel Drive**	
	Freq	**(%)**	**Freq**	**(%)**	**Freq**	**(%)**
Cause of Death						
Direct head only	480	(22)	18	(23)	20	(24)
Direct head chest	431	(20)	13	(17)	12	(14)
Direct head chest abdom	101	(5)	4	(5)	4	(5)
Direct head + other severe	138	(6)	2	(3)	5	(6)
Direct chest only	480	(22)	14	(18)	12	(14)
Direct other severe	329	(15)	13	(17)	15	(18)
Direct no severe	234	(11)	13	(17)	15	(18)
Total	**2193**	**(100)**	77	**(100)**	**83**	**(100)**
Sub-total head	***1150***	***(52)***	***41***	***(49)***	***37***	***(48)***
Sub-total chest	***1012***	***(46)***	***28***	***(34)***	***31***	***(40)***
Location of Most Severe Injury						
Head	730	(33)	29	(38)	29	(35)
Chest	675	(31)	19	(25)	16	(19)
Head chest	253	(12)	9	(12)	9	(11)
Abdomen	118	(5)	4	(5)	3	(4)
Chest abdomen	77	(4)	0	0	3	(4)
Spine	107	(5)	3	(4)	5	(6)
Ext	30	(1)	8	(10)	4	(5)
Head chest abdomen	25	(1)	0	0	2	(2)
Other	178	(8)	5	(6)	12	(14)
Total	**2193**	**(100)**	77	**(100)**	**83**	**(100)**
Sub-total head	***1008***	***(46)***	***40***	***(48)***	***38***	***(49)***
Sub-total chest	***1030***	***(47)***	***30***	***(36)***	***28***	***(36)***

Source: 1988 and 1990 FORS Fatality Files

3.3.4 Body Regions Injured

The cause of death and location of the most severe injury for occupants killed in fatal crashes are shown in Table 3.18, fatalities where the cause of death could not be attributed directly to the crash (eg, heart attack or complications arising in hospital), or where no specific injury detail was recorded, were excluded from this analysis. The 'cause of death' variable is a coding of the most severe injuries (AIS ≥ 4,5,6) by body regions, such that a fatality coded as 'Direct head chest' would have suffered one or more injuries of AIS ≥ 4, 5 or 6 to the head and chest. The 'location of the most severe injury' variable indicates the body region where the injury with the highest AIS value was sustained.

Summing the number of fatalities where a severe head injury was sustained (either on its own or in conjunction with a severe injury to another body region) indicated little difference in the incidence of fatal head injuries across vehicle types (52% passenger cars cf. 49% 4WDs, 48% vans,). A similar calculation for chest injuries revealed a slight preponderance of fatal chest injuries in passenger cars (46%) compared with 4WDs (34%), and to a lesser extent, vans (40%).

Additionally, chest injuries seem to have been over-represented as the 'most severe injury' among passenger car fatalities and under-represented among 4WD fatalities (47% cf. 36%).

There was a slight over-representation of severe external injuries (ie, lacerations or burns) among van occupants who died.

3.3.5 Injuries by Crash Type

The injury analysis was also broken down by crash type and the results for frontal crashes and rollovers are reported in Tables 3.19 and 3.20 respectively. Once again fatalities with indirect cause and unspecified injury detail have been excluded from the totals.

Frontals: Table 3.19 shows that in frontal crashes, severe chest and head injuries were the major cause of fatality among vehicle occupants with no marked differences across the vehicle types. Notably, occupants of 4WDs were comparatively more likely to have an external injury as the most severe one than occupants of passenger cars or passenger vans were (18% cf. 1% and 2% respectively).

Rollovers: The number of vans involved in rollover crashes was relatively small (see Table 3.20), so comparisons are confined to passenger cars and 4WDs. Severe head injuries were the predominant cause of death in fatal rollovers, but were higher among passenger car occupants than among 4WD occupants (58% cf. 41%). Fatal chest injuries, while less common, were slightly more prevalent among passenger car occupants than among 4WD occupants (38% cf. 30%). There was a slight suggestion that 4WD occupants killed in a rollover crash were more likely to sustain a severe spinal injury than passenger car occupants in equivalent crashes. A rollover crash study conducted by MUARC (Rechnitzer & Lane, 1994) found that poor roof integrity in 4WD vehicles resulted in significant vertical and lateral roof crush which in turn was a significant factor contributing to severe spinal injuries.

3.3.5 Ejection and Entrapment

The analysis of ejection and entrapment in fatal crashes for the three vehicle types is broken down by restraint use and crash type as these can have a major influence on outcome severity. As shown in Table 3.21, there was no difference in the incidence of ejection across the three vehicle types for restrained occupants, however unrestrained occupants of 4WDs were slightly over-represented in ejections by comparison with equivalent passenger car occupants (48% cf. 39%), which may be due in part to the over-involvement of 4WDs in fatal rollovers (54% cf. 20% passenger cars).

Table 3.21 also suggests that occupants of 4WDs have lower seat belt wearing rates than occupants of passenger cars (approximately 49% cf. 70%) which may explain the higher incidence of ejection of 4WD occupants than passenger car occupants in rollover crashes (43% cf. 34%, see Table 3.22).

Occupants of 4WDs (restrained or unrestrained) have marginally less likelihood of being trapped in the vehicle following a fatal crash than equivalent occupants of passenger cars or vans (Table 3.21), and are also less likely to be trapped in the vehicle following fatal **frontal** collisions than passenger car and van occupants(25% cf. 32% and 38%, see Table 3.22).

Table 3.19 Final Cause of Death and Location of Most Severe Injury by Vehicle Type for Occupants Killed in *Frontal* Crashes

	Passenger Car		Passenger Van		Four Wheel Drive	
	Freq	**(%)**	**Freq**	**(%)**	**Freq**	**(%)**
Cause of Death:						
Direct head only	**174**	**(19)**	**9**	**(18)**	**2**	**(9)**
Direct head chest	164	(18)	8	(16)	6	(27)
Direct head chest abdom	48	(5)	3	(6)	1	(5)
Direct head + other severe	52	(6)	1	(2)	1	(5)
Direct chest only	235	(25)	13	(27)	2	(9)
Direct other severe	145	(16)	4	(8)	6	(27)
Direct no severe	117	(13)	11	(22)	4	(18)
Total	**935**	**(100)**	**49**	**(100)**	**22**	**(100)**
Sub-total head	***438***	***(47)***	***10***	***(45)***	***21***	***(43)***
Sub-total chest	***447***	***(48)***	***9***	***(41)***	***24***	***(49)***
Location of Most Severe Injury:						
Head	268	(29)	15	(31)	5	(23)
Chest	319	(34)	15	(31)	4	(18)
Head chest	94	(10)	8	(16)	4	(18)
Abdomen	57	(6)	2	(4)	1	(5)
Chest abdomen	45	(5)	0	(0)	1	(5)
Spine	42	(4)	3	(6)	0	(0)
Ext	13	(1)	1	(2)	4	(18)
Head chest abdomen	11	(1)	0	(0)	0	(0)
Other	86	(9)	5	(10)	3	(14)
Total	**935**	**(100)**	**49**	**(100)**	**22**	**(100)**
Sub-total head	***373***	***(40)***	***9***	***(41)***	***23***	***(47)***
Sub-total chest	***469***	***(50)***	***9***	***(41)***	***23***	***(47)***

Source: 1988 and 1990 FORS Fatality Files

Table 3.20 Final Cause of Death and Location of Most Severe Injury by Vehicle Type for Occupants Killed in *Rollover* Crashes

	Passenger Car		**Passenger Van**		**Four Wheel Drive**	
	Freq	**(%)**	**Freq**	**(%)**	**Freq**	**(%)**
Cause of Death:						
Direct head only	117	(34)	3	(21)	12	(27)
Direct head chest	66	(19)	3	(21)	3	(7)
Direct head chest abdom	6	(2)	1	(7)	1	(2)
Direct head + other severe	12	(3)	0	0	3	(7)
Direct chest only	60	(17)	0	0	9	(20)
Direct other severe	43	(12)	5	(36)	7	(16)
Direct no severe	44	(13)	2	(14)	9	(20)
Total	**348**	**(100)**	**14**	**(100)**	**44**	**(100)**
Sub-total head	***201***	***(58)***	***18***	***(41)***	***7***	***(50)***
Sub-total chest	***132***	***(38)***	***13***	***(30)***	***4***	***(29)***
Location of Most Severe Injury						
Head	151	(43)	6	(43)	18	(41)
Chest	74	(21)	2	(14)	10	(23)
Head chest	56	(16)	1	(7)	3	(7)
Abdomen	11	(3)	1	(7)	1	(2)
Chest abdomen	3	(1)	0	0	2	(5)
Spine	17	(5)	0	0	4	(9)
Ext	9	(3)	4	(29)	0	0
Head chest abdomen	1	0	0	0	1	(2)
Other	26	(7)	0	0	5	(11)
Total	**348**	**(100)**	**14**	**(100)**	**44**	**(100)**
Sub-total head	***208***	***(60)***	***22***	***(50)***	***8***	***(57)***
Sub-total chest	***134***	***(39)***	***16***	***(36)***	***3***	***(21)***

Source: 1988 and 1990 FORS Fatality Files

Table 3.21 Ejection and Entrapment for Occupants in Fatal Crashes by Vehicle Type and *Seat Belt Use*

	Passenger Car		Passenger Van		Four Wheel Drive	
	Freq	(%)	Freq	(%)	Freq	(%)
Restrained:						
Ejected	87	(3)	4	(3)	5	(6)
Not Ejected	2797	(97)	135	(97)	79	(94)
Unrestrained:						
Ejected	473	(39)	29	(41)	43	(48)
Not Ejected	736	(61)	42	(59)	46	(52)
Restrained:						
Trapped	833	(30)	40	(31)	20	(24)
Not Trapped	1903	(70)	91	(69)	64	(76)
Unrestrained:						
Trapped	215	(18)	11	(15)	9	(9)
Not Trapped	950	(82)	60	(85)	87	(91)

Source: 1988 and 1990 FORS Fatality Files

Table 3.22 Ejection and Entrapment for Occupants in Fatal Crashes by Vehicle Type and *Crash Type*

	Passenger Car		Passenger Van		Four Wheel Drive	
	Freq	(%)	Freq	(%)	Freq	(%)
Frontal:						
Ejection	160	(8)	17	(13)	4	(7)
Entrapment	629	(32)	46	(38)	16	(25)
Side:						
Ejection	135	(8)	7	(20)	3	(16)
Entrapment	393	(25)	6	(18)	3	(16)
Rollover:						
Ejection	392	(34)	19	(20)	52	(43)
Entrapment	181	(16)	9	(9)	14	(12)

Source: 1988 and 1990 FORS Fatality Files

3.4 CONCLUSIONS

Overall, the findings suggested that the pattern of crash type and injury outcomes for 4WD vehicle occupants was different in many respects from that for occupants of passenger cars and passenger vans. The findings for occupants of utilities/light trucks generally fell somewhere in between but were closer to those for 4WDs than to those for passenger cars or passenger vans.

The main trends evident in these data were as follows:

- Four-wheel-drive occupants were over-involved in crashes (both casualty and fatal) occurring on roads where the speed limit was 75 km/h or greater. This result is probably a function of greater exposure of 4WD vehicles on rural roads with higher speed zones.
- Four-wheel-drives were over-involved in rollover crashes (in both high and low speed zones), and their occupants sustained more serious injury outcomes. The latter finding may have been because 4WD occupants were more likely to be unrestrained and ejected during the crash, than occupants of passenger cars or vans. Ejection has been found to be a significant factor in rollover fatalities and is related to a significant lack of roof integrity in 4WD vehicles by comparison with other vehicle types (see Rechnitzer & Lane, 1994).
- Rollover crash configurations were 12 times more likely to occur in high than low speed zones, and high speed zone rollovers accounted for 80% of injuries sustained in rollover crashes.
- Drivers of 4WDs involved in casualty or fatal crashes tended to be male and aged between 26-55 years. The proportion of younger (< 26 years) drivers involved in these crashes was slightly higher for passenger cars than for the other vehicle types.
- Passenger vans were over-involved in fatal outcomes in head-on crashes in low speed zones (< 75 km/h) and their occupants were more likely to be trapped in the vehicle in these crashes. This is probably due to the more limited crumple space available in passenger vans.
- Head, and to a lesser extent, chest injuries were the most common causes of death in fatal crashes. Severe chest injuries were slightly under-represented among 4WD fatalities by comparison with passenger car fatalities.
- In fatal frontals, severe chest injuries were again under-represented among 4WD occupants, particularly as the most severe injury, by comparison with passenger car occupants.
- In fatal rollovers, chest and to a lesser extent, head injuries were under-represented as the cause of death and most severe injury for 4WD occupants by comparison with passenger car occupants; however, killed 4WD occupants were more likely to have sustained a severe spinal injury than occupants killed in fatal rollovers in other vehicle types.
- Occupants of 4WDs involved in fatal crashes were more likely to be unrestrained and ejected, and less likely to be entrapped than occupants of passenger cars and passenger vans.

4. CRASHED VEHICLE STUDY

Detailed and reliable information on impact direction, vehicle damage and personal injury to establish causal relationships of occupant injuries is generally not available in mass crash injury data in this country. Thus, it was necessary to undertake a detailed retrospective examination of a representative sample of crashed vehicles to provide definitive information on the sources of injury to vehicle occupants in typical on-road crashes. This enabled details on improvements in vehicle design and construction to be identified so that reductions in the frequency and/or severity of these injuries could be achieved. The information included details on the type, severity and location of all injuries sustained by the vehicle occupants for each seating position and type of vehicle.

4.1 METHOD

The method developed from previous passenger car studies was adopted here. This involved the detailed assessment of the extent of occupant injuries and the vehicle damage for a sample of crashes involving post-1985 Four-Wheel-Drives (4WDs), light commercial vans and utilities (especially those capable of a 4WD transmission). However, in contrast to previous passenger car studies the criterion for inclusion in this study was "*vehicle-based*" rather than "*person-based*" (see "Selection Criteria" below). As the study was primarily concerned with secondary safety (i.e., aspects of a vehicle's crashworthiness performance), in-depth analysis at-the-scene was not attempted. Most of the crashes occurred in Victoria and 45% of the crashes occurred in rural areas.

4.1.1 Selection Criteria

Vehicle Suitability: The criterion for the selection of vehicles was that they had to have sustained over $5,000 damage as a result of a crash. However, vehicles fitting this criterion which were repairable proved difficult to locate, and the final sample of crashed vehicles comprised those which were mainly "write-offs". Most of these were located at a salvage auction yard in Melbourne.

Occupant Suitability: Ethical considerations required that all occupants (injured or not) had to agree to participate in this study. While occupants are required by law to be belted in their vehicles, a number of them nevertheless do not wear seat belts. It was necessary to include patients in the crashed vehicle sample who were both belted and unbelted so as not to bias the study and overlook another set of problems for a subgroup of vehicle occupants most at risk.

Crash Suitability: Because of the difficulty in interpreting the effects of multiple collisions in terms of which crash caused which injury, only cases where the impacted vehicle sustained most damage from a single impact were included. The impacted object could have been either another car, a truck, or a movable or immovable object, including rollovers.

4.1.2 Occupant Assessment

The assessment and classification of injuries sustained by road trauma patients (including injury severity judgements) requires specialised medical training and research skills. Two State Registered Nurses (SRNs) with additional research qualifications were employed by MUARC during the course of this study to undertake these duties and were extensively trained in the collection of injury data for research purposes including making Abbreviated Injury Score (AIS) assessments of injury severity. A proforma was developed to provide a standardised format for the collection of patients' medical, vehicle, and crash information (see Attachment 1). This was trialed and modified prior to commencement of its use in the project. As many of the occupants were either uninjured or only slightly injured, most of the assessments were conducted using telephone interview procedures, although these accounts were checked against hospital records where this was possible.

4.1.3 Hospital Participation

Approval to approach and interview patients in hospital, where necessary, or to access their medical records was obtained from the ethics committees of ***eleven*** major public hospitals in Victoria. These included the Alfred Hospital (and Trauma Centre), Austin Hospital (Spinal Unit), Ballarat Base Hospital, Box Hill Hospital, Dandenong and District Hospital, Geelong Hospital, La-Trobe Regional Hospital (Moe & Traralgon campuses), Monash Medical Centre, Royal Melbourne Hospital, Preston and Northcote Community Hospital and Western Hospital. This approval was subject to obtaining the patient's agreement to participate, as well as ensuring confidentiality of the information.

4.1.4 Vehicle Assessment

The detailed assessment of the crashed vehicles was a critical task in accurately specifying vehicle involvement in patient injuries and has been previously undertaken in two earlier MUARC studies (Fildes, Lane, Lenard & Vulcan, 1991; 1994). A mechanical engineer trained in undertaking these inspections and in making judgments of injury and vehicle component interactions was employed for this task (see Attachment 1 for a full description of the inspection process). The National Highway Traffic & Safety Administration (NHTSA) in Washington D.C. kindly provided the National Accident Sampling System's (NASS) crash inspection proforma (including training and coding manuals) as well as the computer software CRASH3 for computing Delta-V (see Attachment 3). Figure 4.1 shows the NASS vehicle proforma for coding impact direction and vehicle region.

4.1.5 Calculation of Impact Velocity

Impact velocity is defined as the change in velocity from the moment of impact until the study vehicle separated from its impacting source (delta-V). This value was calculated using the CRASH 3 program made available by the National Highway Traffic Safety Administration. It should be noted that the delta-V values computed are best estimates of impact velocity and can be subject to error from the assumptions made in the program and vehicle stiffness values used in making these calculations. In this study, American stiffness values had to be used in the calculations of delta-V for vehicles of the same sizes as the Australian vehicles as local figures were not readily available. These errors could be reduced to some degree if appropriate stiffness values for Australian vehicles were to be provided by the local manufacturers.

Calculation of the delta-V values is dependent upon having mass, stiffness, and crush profile data on the 'B' vehicle involved in the impact with the target vehicle. Because of the large number of single-vehicle impacts (mainly rollovers) in the crashed vehicle file, and the difficulty of obtaining details of the 'B' vehicle prior to repairs being undertaken (due mainly to the vehicle based selection method), delta-V values could only be calculated for 42 of the 144 cases (29%). Equivalent Barrier Speed (EBS) estimates were calculated for 88 cases (61%), where EBS is defined as the speed which would cause equivalent damage to the target vehicle if it was driven into a rigid barrier. This allowed a test of 'goodness of fit' of the obtained distribution of delta-Vs against the distribution of EBSs. As with delta-Vs, EBS values could not be calculated for rollovers, which accounted for 39 (27%) of the crash cases in this sample.

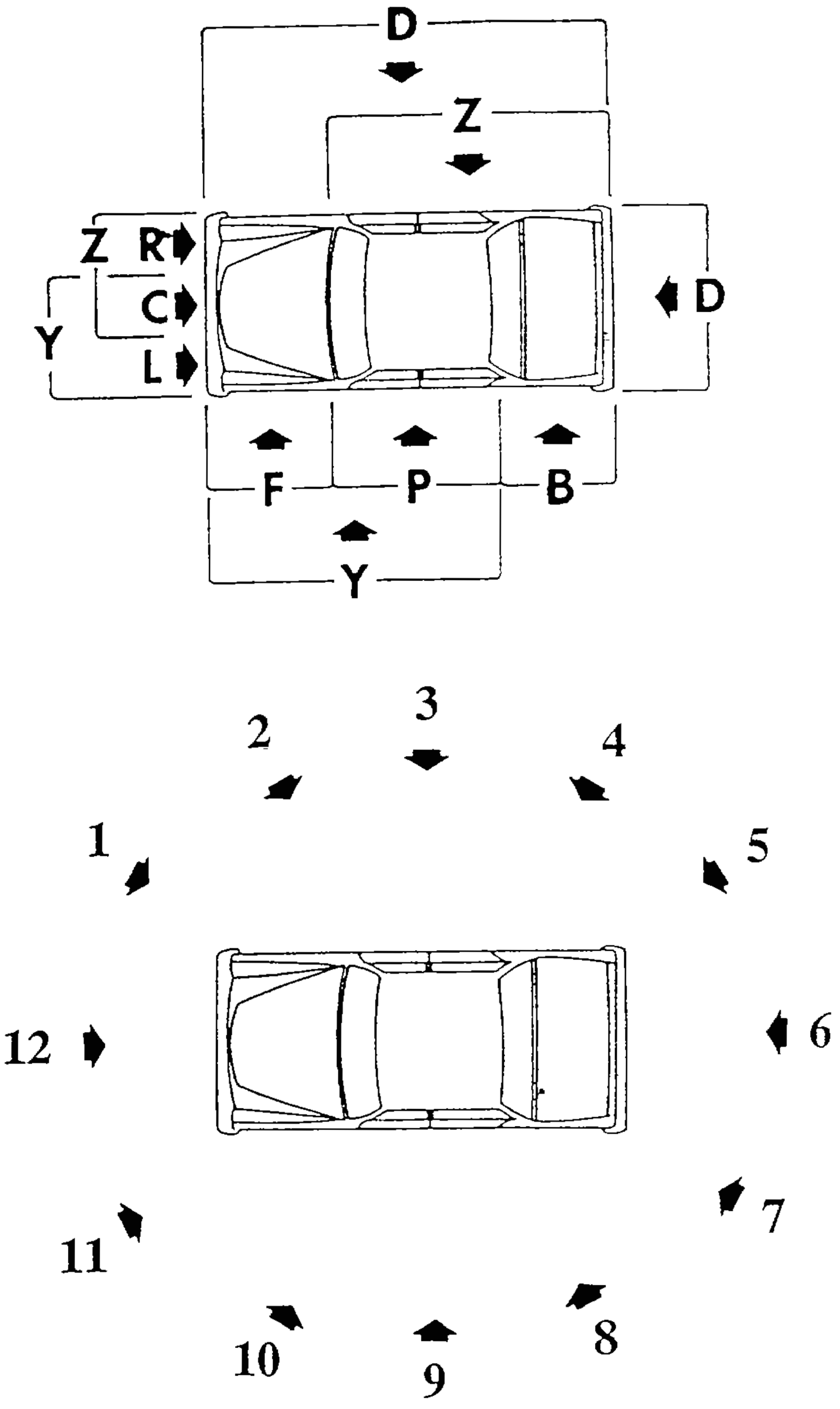


Figure 4.1 National Accident Sampling System proforma used for coding vehicle impact location and direction (courtesy of NHTSA).

4.1.6 Procedure

Once a target crashed vehicle was located, contact was made with the driver and/or registered owner of the vehicle to explain the study objectives and to seek the signed written consent of the occupants to participate in the study. Only 5 cases were rejected because the occupant or owner failed to give their consent to participate. Once consent was received, these occupants were interviewed by the nurse to obtain injury and crash details (see Attachment 2 for consent and occupant injury forms). Interviews were conducted mainly over the telephone using standard interviewing procedures, although some hospital and home face-to-face interviews were conducted. Occupants' injury reports were verified against any hospital or medical records where these existed.

These injury details were passed on to the engineer who then conducted a detailed inspection of the vehicle to determine the extent of damage and the interactions between injuries and vehicle components (see Attachment 3 for vehicle inspection forms). Where a second vehicle was involved and could be located, it was briefly examined to complete the details required to explain the damage and to calculate the impact velocity (details of injuries to occupants in the second vehicle were not collected). Each case was fully documented and coded into a computer database for subsequent analysis. A subsequent volume to this report provides a one-page summary of each occupant's injuries and is available on request from FORS.

4.1.7 Coding Injuries & Contacts

Injuries: The National Accident Sampling System (NASS) for classifying and coding occupant injuries includes 20 separate body region injury codes. To simplify presentation of the results (especially given the small patient numbers) these were subsequently grouped into **nine** discrete body region categories, namely the head, face, chest, abdomen, pelvis, upper limb (i.e., arm and shoulder), thigh and knee, lower leg, and spine (including the neck).

Injury Contact Sources: The NASS classification further allows for coding injury source using 82 vehicle components as points of contact. Again, to simplify presentation of the results for this limited number of cases, these were grouped into **sixteen** vehicle regions, including the windscreen and header, steering wheel, steering column, instrument panel, console, pillars, side glazing (window and door frame), door panel (and rail), roof surface, seats, seat belts, other occupants, floor, exterior contacts, non-contacts, and others or unknown.

4.2 VARIABLES & DATA ANALYSES

A number of independent variables were of particular interest in the crashed vehicle study. These included patient characteristics, injuries sustained (including AIS severity), vehicle damage and extent of deformation, direction of principal force, severity of impact (delta-V), component and equipment failures, cabin distortion and intrusions, use of restraints, and an assessment of the source of all injuries. The inspection method used in this study has been shown to be the only objective and accurate means of making assessments of seat-belt wearing behaviour (Cromark, Schneider & Blaisdell, 1990).

The dependent variables comprised crash and injury involvement rates per 100 vehicles or occupants relative to the population of crashes investigated in the follow-up study of crashed vehicles. Sources of injury inside and outside the vehicle were especially important in this study. Presentation of the results was confined to reporting percentage differences in involvement and rank ordering of involvement rates for injuries per body region and vehicle components.

4.3 OVERALL RESULTS

The final database comprised details on 144 vehicles and 197 occupants. The crashed vehicle database contains information on 572 variables for each crash investigated. The population characteristics of the sample are shown in Table 4.1, with comparisons from the crashed vehicle study of passenger cars (CR 95, Fildes, Lane, Lenard & Vulcan, 1991) where appropriate. One feature of the database which should be borne in mind when interpreting the analyses is that the number of front-left (27) and rear-seat (12) occupants is much too small to make meaningful comparisons across seating positions or to draw reliable conclusions.

4.3.1 Crash Type

Frontal crashes predominated the sample accounting for just over half of all crashed vehicles inspected. Side impacts were well under-represented by comparison with the sample of crashed passenger cars (16% cf. 35%) and rollovers were over-represented (27% cf. 5%).

4.3.2 Type of Vehicle

Roughly one third of vehicles fell into each of the three body types - 4WDs, Vans & Utes. Table 4.2 lists the various makes and models of vehicles in the crashed vehicle fleet. The fleet contains a representative spread of manufacturers of these vehicles and covers the majority of models available in this country. Unfortunately, there are no accurate figures available on the proportions of vehicle models in the current vehicle population in Victoria nor their relative exposure, making it difficult to gauge relative involvement rates. A large majority (82%) of the vehicles had manual transmissions while the rest were automatics. There were no front-wheel-drive only vehicles in this sample. Over half (57%) of the vehicles had rear-wheel drive transmissions and the remaining 43% of the total sample were four-wheel drives. Most of the utes (67%) and all vans (100%) had rear wheel drive transmissions.

4.3.3 Occupant Characteristics

Seventy-three percent of occupants were drivers, 18% were front-left seat passengers, while 9% were rear seat passengers. The slightly higher proportion of drivers compared with the passenger car file (73% cf. 62%) probably reflects higher exposure rates of driver-only vehicles in the "*van*" and "*ute*"categories (a high proportion of these were commercial vehicles with no rear seat, rather than "*people carriers*"). There was a strong over-representation of males in the sample, compared with population figures. The majority of occupants (54%) were aged between 26-55 years, and a further 27% 17-25 years old. It is noteworthy that those aged over 55 were under-represented in crashes involving 4WDs, vans or utes, compared with passenger car crashes (8% cf. 18%) and that males were strongly over-represented (72% cf. 49%).

4.3.4 Seat belt Wearing

Of the 172 occupants whose belt-wearing status could be determined, 169 (98%) of them were belted at the time of the collision. This is slightly higher than population wearing rates (95%) and markedly higher than the rate observed among the sample of hospitalised occupants in the passenger car study (82%). The 98% wearing rate may be a slight over-estimation since it does not take into account the 11% of drivers whose belt wearing status could not be determined with certainty. However, it may also be, in part, a function of the lower injury severity levels for these special purpose vehicles, brought about by the change to a vehicle-based entrance criterion in this study. While the numbers were small, there was no difference apparent in seatbelt wearing rates across seating positions (for occupants whose belt wearing could be determined).

Table 4.1 Population Characteristics of the Crashed 4WD, Van, Ute File Compared with the Crashed Passenger Vehicle File

CHARACTERISTIC	CRASHED VEHICLE 4WD, VANS & UTES (n=144)	CRASHED VEHICLE PASSENGER CAR (n=227)
1. IMPACT VELOCITY		
Delta-V:		
Mean	35.5 km/h	45.4 km/h
Standard Deviation	16.7 km/h	23.3 km/h
Range	15-100 km/h	3-111 km/h
EBS:		
Mean	27.6 km/h	
Standard Deviation	16.6 km/h	
Range	5-100 km/h	
2. CRASH TYPES		
Frontal	55%	60%
Side impact	16%	35%
Rear end	1%	0%
Rollover	27%	5%
Other	1%	
3. VEHICLE TYPES		
4WD	32%	
Vans	35%	
Utes	33%	
4. SEATING POSITION		
Driver	73%	62%
Front-Left	18%	25%
Rear	9%	13%
5. OCCUPANT'S SEX		
Males	72%	49%
Females	28%	51%
6. OCCUPANT'S AGE		
< 17 years	11%	8%
17 - 25 yrs	27%	27%
26 - 55 yrs	54%	47%
56 - 75 yrs	7%	15%
> 75 years	1%	3%

Note: Delta-V values are based on 42 cases and EBS values are based on 88 cases.

Table 4.2 List of the Type of Vehicles in the Crashed Vehicle File (n=144)

VEHICLE MAKE/MODEL		NUMBER	PERCENTAGE OF TOTAL SAMPLE (N=144)	MASS (RANGE)
Utes				
Holden	Rodeo	11	7.60%	1310-1590 kg
Toyota	Hilux	12	8.30%	1155-1470 kg
Ford	Courier	5	3.50%	1290-1555 kg
Nissan	Navara	9	6.30%	1260-1660 kg
Mitsubishi	Triton	4	2.80%	1230-1570 kg
Mazda	B2200	2	1.40%	1465-1480 kg
Mazda	Bravo	1	0.70%	1470-1510 kg
Nissan	4x4	1	0.70%	1260-1620 kg
		45		
Vans				
Mitsubishi	Express	9	6.30%	1250-1296 kg
Ford	Econovan	7	4.90%	1230-1404 kg
Toyota	Hiace	6	4.20%	1445-1510 kg
Toyota	Tarago	5	3.50%	1430-1745 kg
Toyota	Liteace	6	4.20%	1070-1160 kg
Ford	Spectron	2	1.40%	1250 kg
Nissan	Nomad	2	1.40%	1350-1450 kg
Holden	Scurry	2	1.40%	750 kg
Holden	Shuttle	1	0.70%	1440 kg
Mitsubishi	Starwagon	2	1 40%	1291-1391 kg
Nissan	Urvan	2	1.40%	1530-1650 kg
Nissan	Vanette	1	0.70%	1200-1280 kg
Suzuki	Super Carry	1	0.70%	755-815 kg
Toyota	Townace	1	0.70%	1190-1200 kg
Mazda	E1800	2	1.40%	1230 kg
Mazda	E2200	2	1.40%	1355-1445 kg
		51		
4WD				
Toyota	Land Cruiser	8	5.60%	1940-2145 kg
Nissan	Patrol	5	3.50%	1906-2028 kg
Rover	Range Rover	6	4.20%	1780-2017 kg
Suzuki	Vitara	7	4.90%	920-1152 kg
Rover	Land Rover	3	2 80%	1810-1920 kg
Toyota	4-Runner	4	2.80%	1490-1590 kg
Ford	Maverick	2	1.40%	1932-2130 kg
Mitsubishi	Pajero	5	3.50%	1590-1660 kg
Lada	Niva	1	0.70%	1170 kg
Suzuki	Sierra	2	1.40%	920-940 kg
Holden	Drover	2	1.40%	960-990 kg
Daihatsu	Feroza	1	0.70%	1125 kg
Holden	Jackaroo	1	0 70%	1810 kg
		48		

NB: A summary of each of these cases is available in the supplementary volume to this report (FORS Report No. CR 150a).

4.3.5 Intrusions and Deformations

Table 4.3 lists the rank ordering of intrusions in the front and rear seat occupant areas where intrusion was defined in relation to the space inside the vehicle likely to be occupied by passengers. It should be noted that while front-seat intrusions were based on the total sample of vehicles, rear seat intrusions were based on a subset of these vehicles which had a rear seat occupant area, thereby excluding two-door utilities or vans with no rear-seats fitted. Given that the sample comprised several vehicles without rear seating positions, it is not surprising that the number of front seat intrusions far exceeded the number of rear seat intrusions.

Table 4.3 Rank Ordering of Vehicle Damage Intrusions for Crashes by Front and Rear Seating Positions

FRONT SEAT INTRUSION (n=144)			REAR SEAT INTRUSION (n=84)*		
ITEM	**FREQ**	**(%)**	**ITEM**	**FREQ**	**(%)**
Steering Assembly	50	(35)	Roof	13	(16)
Toe pan	49	(34)	Roof side rail	11	(13)
Instrument panel	42	(29)	Door panel	7	(8)
A-pillar	35	(24)	C-pillar	5	(6)
Roof side rail	31	(22)	Side panel	4	(5)
Roof	30	(21)	A-pillar	1	(1)
Door panel	29	(20)			
B-pillar	25	(17)			
W'screen/header	20	(14)			
Side panel	1	(1)			
Other	5	(4)			
Totals	**317**			**41**	

** Rear Seat Intrusion analysis is based on only those vehicles with rear seats fitted. Steering assembly intrusions in the top part of Table 4.3 refer to cases where there was movement in either a longitudinal, lateral, or vertical plane (movements in more than one plane were only scored as a single movement). The breakdown of intrusions into the total numbers of individual plane movements for all crashes is detailed below.*

Steering Assembly Movements by Direction of Displacement

	FREQ	**(%)**
Lateral	34	(24)
Longitudinal	34	(24)
Vertical	23	(16)

The most common front seat intrusions were the steering assembly, toe pan, instrument panel and A-pillar. These structural components were also among the top five front seat intrusions for passenger cars (Fildes et al., 1991). The most common intrusions into the rear seating area were the roof surface and side rail which were also the most common rear seat intrusions for passenger cars (Fildes et al., 1991). Notably, front and rear intrusions from the door panel ranked only 7th and 3rd respectively, compared with 2nd and 1st for passenger car crashes. The lower part of Table 4.3 shows that for steering assembly intrusions displacement direction was more often longitudinal or lateral (24% ea.), rather than vertical (16%).

Tables 4.4 and 4.5 show the breakdown of front and rear seat intrusions by vehicle type. Overall, vans and 4WDs have more front seat intrusions than utilities. Further, there are some noteworthy differences in the pattern of common front seat intrusions across the three vehicle types. Vans have a preponderance of toe pan and instrument panel intrusions (59% & 55%), whereas utility intrusions were mainly to the roof surface, side rail, B pillar and door panel (22% each). Four-wheel-drives showed a somewhat similar pattern to utes with front intrusions mainly to the roof surface, side rail and the A-pillar. The intrusion pattern for 4WDs can partly be explained by the over-representation of these vehicles in rollover crashes.

Table 4.4 Front Seat Intrusions for Crashes by Vehicle Type

	FRONT SEAT INTRUSION					
	UTILITIES (n=45)		VANS (n=51)		4WD (n=48)	
COMPONENT	FREQ	(%)	FREQ	(%)	FREQ	(%)
Toe pan	8	(18)	30	(59)	11	(23)
Instrument panel	4	(9)	28	(55)	10	(21)
Door panel	10	(22)	12	(24)	7	(15)
Roof	10	(22)	4	(8)	16	(33)
Roof side rail	10	(22)	6	(12)	15	(31)
A-pillar	8	(18)	12	(24)	15	(31)
B-pillar	10	(22)	6	(12)	9	(19)
W/screen/header	5	(11)	3	(6)	11	(23)
R/screen/header	2	(4)	0	0	0	0
Windscreen	0	0	0	0	1	(2)
Rear Compartment	1	(2)	0	0	1	(2)
Outer Object	0	0	1	(2)	0	0
Side panel	0	0	0	0	1	(2)
Totals	**68**		**102**		**97**	

Table 4.5 Rear Seat Intrusions for Crashes by Vehicle Type

	REAR SEAT INTRUSION*					
	UTILITIES (n=22)		VANS (n=21)		4WD (n=41)	
COMPONENT	FREQ	(%)	FREQ	(%)	FREQ	(%)
Door panel	6	(27)	0	0	1	(2)
Roof	3	(14)	2	(10)	8	(20)
Roof side rail	1	(5)	3	(14)	7	(17)
A-pillar	0	0	0	0	1	(2)
C-pillar	1	(5)	2	(10)	2	(5)
Side panel	0	0	3	(14)	1	(2)
Totals	**11**		**8**		**20**	

* *Rear Seat Intrusion analysis is based on only those vehicles with rear seats fitted*

Roughly 50% of the 4WDs and utes with rear seats fitted had intrusions into this area and the proportion was slightly less for vans (38%). There was no clear pattern of differences between the vehicles in rear seat intrusions, although the numbers of vehicles eligible for this analysis was probably too small to show strong trends. The pattern of rear seat intrusions for 4WDs was again consistent with their over-invlovement in rollovers.

4.3.6 Impact Velocity

Figure 4.1 shows the delta-V and/or the Equivalent Barrier Speed (EBS) distributions of impact velocity observed in the various subsets of the sample of crashes. The modal value of the *delta-V* distribution was 18-24 km/h, with a range of impact speeds from 15 to 100 km/h. Seventy percent of all delta-V values were equal to or less than 42 km/h. The modal value of the *EBS* distribution was 12-24 km/h, with a range of impact speeds between 5 and 100 km/h. The 70th percentile value for EBS was 36 km/h.

The curves of the delta-V and the EBS distributions are roughly similar although the EBS values on the whole tend to be slightly lower. Notably, both the delta-V and EBS values observed in this sample of crashes were lower than those for passenger car crashes, a result which could be partially attributable to the 'hospitalised' selection criterion for the passenger car study.

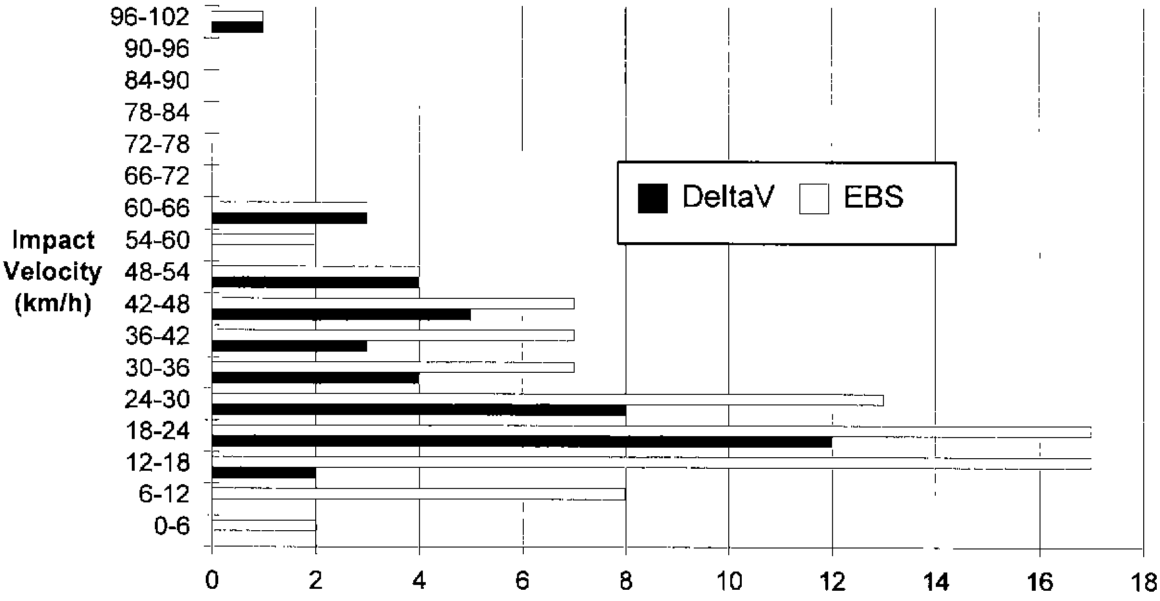


Figure 4.2 Distribution of delta-V and Equivalent Barrier Speed (EBS) values for the sample of 42 and 88 4WD, Vans and Utility vehicles respectively.

4.3.7 Entrapments and Ejections

Table 4.6 shows that there were only seven entrapments (3 full, 4 partial) in the sample, all among belted occupants. Table 4.7 reveals there were no ejections of occupants whose belt-wearing status was known or could be determined, however, there was one ejection of an occupant of unknown belt-wearing status. Note that cases where part of the occupant may have been transiently out of the vehicle during the crash but subsequently came to rest inside the vehicle were treated as non-ejected in this analysis.

Table 4.6 Entrapment Analysis for Belted and Unbelted Occupants

ENTRAPMENTS	BELTED		UNBELTED	
	FREQ	(%)	FREQ	(%)
No entrapment	155	(96%)	3	(100%)
Full entrapment	3	(2%)	0	
Partial entrapment	4	(2%)	0	
Total	**162**	**(100%)**	**3**	**(100%)**

The total number of cases of entrapment and no entrapment is less than the total number of occupants (162 cf. 197) due to the difficulty in assigning entrapment status retrospectively.

Table 4.7 Ejection Analysis for Belted and Unbelted Occupants

EJECTIONS	BELTED		UNBELTED	
	FREQ	(%)	FREQ	(%)
No ejection	169	(98%)	3	(2%)
Full ejection	0	(0%)	0	(0%)
Partial ejection	0	(0%)	0	(0%)
Total	**169**	**(98%)**	**3**	**(2%)**

The total number of cases of ejection and non-ejection is less than the total number of occupants (169 cf. 197) due to the difficulty in assigning "partial ejection" retrospectively.

4.4 INJURIES

The study was especially interested in the types of injuries and their sources inside the vehicle. Analysing the injury and contact source combinations provides a means of identifying particular components inside the vehicle that are major causes of injury to occupants in these crashes and thus require intervention effort. All injury analyses are based on the 'injured' subset of the total occupant sample. Injury analyses broken down by vehicle type (4WDs, Vans, and Utes) are reported for **drivers** only to avoid confounding vehicle-type effects with seating position effects. A further limitation was the small number of occupants in other seating positions. The small number of rear occupants is not surprising given the seating configurations of the vehicles under investigation.

It should also be noted that in this crashed vehicle study assumptions about comparable accident severity across the 3 vehicle types cannot be made because (1), cases were not selected according to an 'occupant hospitalisation' criterion; (2), vans have a lower market value and hence a higher scrappage rate than utilities or 4WDs; and (3), 4WDs are over-represented in rollovers by comparison with vans or utilities. Similarly, comparisons between injury outcomes for this sample of vehicles and those for the crashed passenger car sample do not accurately reflect the relative crashworthiness of the various vehicle types.

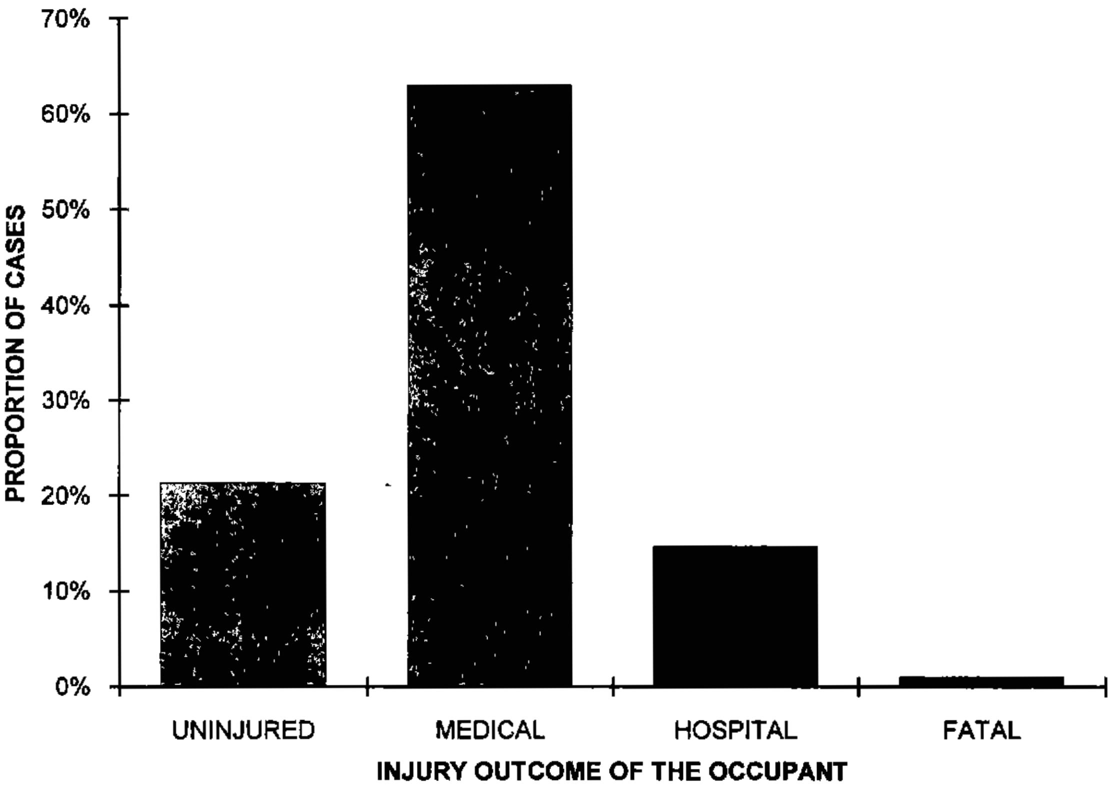


Figure 4.3 Injury outcome for all occupants in all collisions

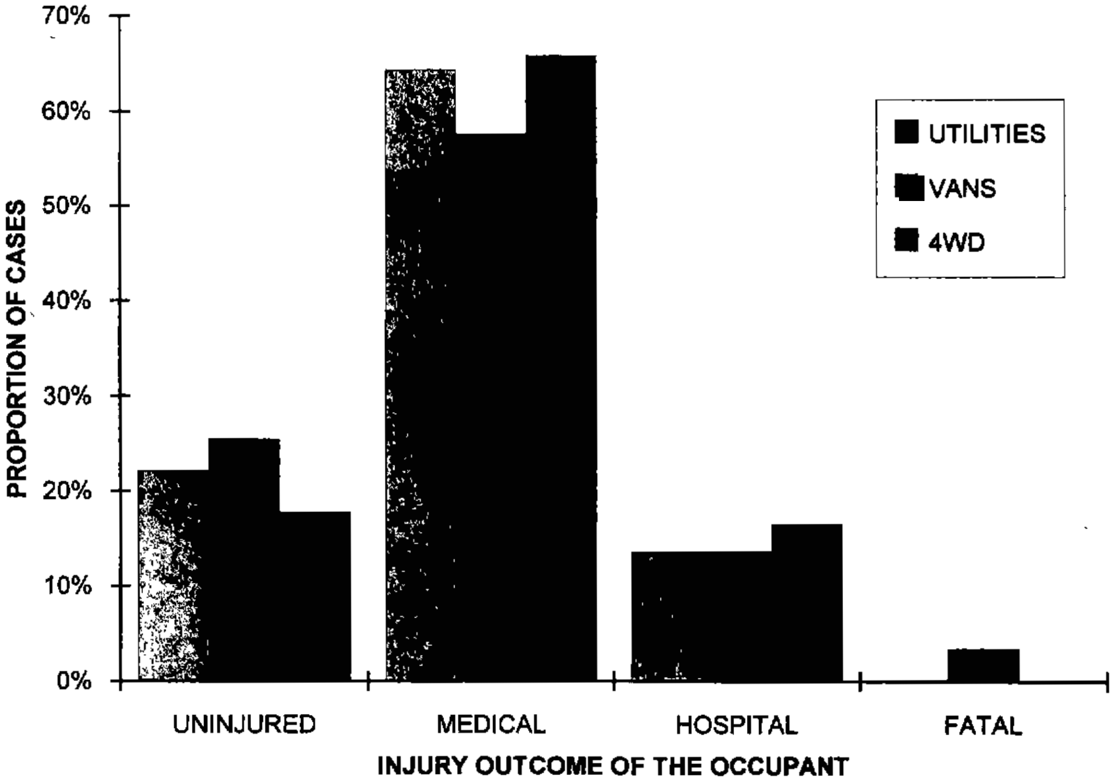


Figure 4.4 Injury outcome for occupants in all collisions by vehicle type

4.4.1 Extent of Injury

Figure 4.2 shows that the majority of occupants (63%) in this study received only minor injuries requiring medical treatment. Furthermore, the proportion of occupants who were uninjured was greater than the proportion who were hospitalised (21% cf. 15%). The fact that this sample of vehicle occupants was relatively uninjured by comparison with occupants in the passenger vehicle study (97% of whom were either hospitalised or killed) is most likely due to the fact that cases were selected according to a vehicle rather than a person-based criterion (i.e., being 'written-off'). Injury outcomes for the different vehicle types (Figure 4.3) suggest that occupants of 4WDs are marginally more likely to sustain injuries requiring medical treatment or hospitalisation than occupants of utes or vans.

4.4.2 Body Regions Injured

Table 4.8 shows that drivers sustained marginally more injuries on average than other occupants (2.8 cf. 2.5 for front left passengers and 1.7 for rear). The most frequent body region injured among **drivers** was upper limbs, followed by knee/thigh, spine/neck and chest. For **front-left passengers** the most frequent body region injured was also upper limbs, followed by head, face, chest and knee/thigh. Body regions injured for **rear passengers** were mainly upper limbs, spine/neck and face, although this is not an accurate indication of regions likely to be injured by these occupants given their small number in this study

Table 4.9 highlights the minor nature of injuries to occupants in this study. For the crashes sampled the probability of any vehicle occupant sustaining a severe injury (AIS>2) was roughly 2 in 10 (cf. 6 in 10 for the passenger car study), and the average Injury Severity Score was only 5.2 (cf. 17.8 for the passenger car study). However, comparisons between the current study and the earlier passenger car study are difficult due to the different selection criteria used. This difference alone could account for the large differences in injury outcomes found between the two studies. Further, as previously mentioned, the small number of front-left and rear-seat occupants makes comparisons of probability of serious injury across seating positions very difficult.

Table 4.10 shows that drivers of vans had fewer injuries to the upper limbs and chest, but more injuries to the lower leg and foot by comparison with drivers of utilities or 4WDs. While the average number of body regions injured was the same across vehicle types (2.8 ea.), the injuries sustained by drivers of vans were more severe (see Table 4.11). The probability of serious injury indices and the average injury severity scores for drivers of vans were markedly higher than those for drivers of utes or 4WDs.

Table 4.8 Body Region Injured by Seating Position for All Collisions

BODY REGION INJURED	DRIVERS (n=76)		FRONT LEFT (n=18)		REAR (n=4)	
	ALL %	(AIS>2) (%)	ALL %	(AIS>2) (%)	ALL %	(AIS>2) (%)
Head	27	(3)	33	(4)	17	0
Face	26	(1)	30	0	25	0
Chest	33	(3)	30	(4)	17	(8)
Abdomen	15	(2)	11	(4)	8	0
Pelvis	15	(1)	11	0	8	0
Upper limb	61	(2)	56	0	42	0
Knee & thigh	38	(2)	30	0	8	(8)
Lower leg & foot	30	(3)	22	0	0	0
Spine & neck	35	0	26	0	33	0
Other	1	0	0	0	1	0
Average/Occupant	**2.8**	**(0.2)**	**2.5**	**(0.2)**	**1.7**	**(0.2)**

Figures for ALL injuries refers to the percentage of injured occupants who had at least 1 injury in that particular body region (of any level of severity). Figures in parenthesis show the percentages for serious injuries only (AIS>2). Average/occupant = mean number of body regions injured per occupant for all injuries and serious (AIS>2) injuries.

Table 4.9 Seating Position by Level and Probability of a Serious Injury

SEATING POSITION	INJURED OCCUPANTS	AV. ISS*	PROBABILITY OF SERIOUS INJURY		
			AIS>2	ISS>15	ISS>25
Driver	116	5.5	0.21	0.05	0.03
Front-left	27	4.7	0.11	0.07	0
Rear	12	3.9	0.25	0.08	0.08
Total (Averages)	**155**	**(5.2)**	**(0.19)**	**(0.06)**	**(0.03)**

* *Injury Severity Score (ISS) is a generally accepted measure of overall severity of injury from road trauma (Baker et al., 1980). It is calculated by adding the square of the 3 highest Abbreviated Injury Scores (AIS) recorded for each of 3 body regions injured.*

Table 4.10 Body Region Injured for Drivers by Vehicle Type

BODY REGION INJURED	UTILITES		VANS		4WD	
	(n=35)		(n=39)		(n=42)	
	ALL %	(AIS>2) (%)	ALL %	(AIS>2) (%)	ALL %	(AIS>2) (%)
Head	29	(3)	26	(8)	26	0
Face	29	0	21	(3)	29	0
Chest	40	(6)	23	(5)	36	0
Abdomen	14	0	15	(5)	14	0
Pelvis	20	(3)	13	0	12	0
Upper limb	60	0	54	(5)	69	0
Knee & thigh	29	0	49	(5)	36	0
Lower leg & foot	20	0	49	(8)	21	(2)
Spine & neck	37	0	33	0	33	0
Other	3	0	0	0	0	0
Average/Occupant	**2.8**	**0**	**2.8**	**(0.4)**	**2.8**	**(0.02)**

Figures for ALL injuries refers to the percentage of injured occupants who had at least 1 injury in that particular body region (of any level of severity). Figures in parenthesis show the percentages for serious injuries only (AIS>2). Averages/occupant = mean number of body regions injured per occupant for all injuries and serious (AIS>2) injuries.

Table 4.11 Vehicle Type by Level and Probability of a Serious Injury

VEHICLE TYPE	INJURED DRIVERS	AV. ISS*	PROBABILITY OF SERIOUS INJURY		
			AIS>2	ISS>15	ISS>25
Utilities	35	5.9	0.14	0.06	0.03
Vans	39	7.1	0.46	0.1	0.08
4WD	42	3.6	0.02	0	0
Total (Averages)	**116**	**(5.5)**	**(0.20)**	**(0.05)**	**(0.03)**

* *Injury Severity Score (ISS) is a generally accepted measure of overall severity of injury from road trauma (Baker et al., 1980). It is calculated by adding the square of the 3 highest Abbreviated Injury Scores (AIS) recorded for each of 3 body regions injured.*

4.4.3 Sources of Injury

Table 4.12 shows that the most prominent sources of injury for ***drivers*** were non-contacts (i.e., injuries such as whiplash where no contact was made with any vehicle component), seat-belts and the instrument panel, but of those, only the instrument panel was a source of severe injury (4% of injured drivers). Notably, the steering wheel was the fourth most frequent source of injury to drivers (26%) in contrast to the passenger car study where it was the most frequent source (53%).

Table 4.12 Points of Contact for Injured Occupants for All Collisions

POINTS OF CONTACTS	DRIVERS		FRONT LEFT		REAR	
	(n=116)		(n=27)		(n=12)	
	ALL	(AIS>2)	ALL	(AIS>2)	ALL	(AIS>2)
	%	(%)	%	(%)	%	(%)
Windscreen/header	9	0	7	0	0	0
Steering wheel	26	0	0	0	0	0
Steering column	7	0	0	0	0	0
Instrument panel	35	(4)	33	0	0	0
Console	3	0	0	0	0	0
Pillar	3	(1)	7	0	0	0
Sideglaze	10	(1)	15	0	17	0
Door panel	14	(1)	11	0	0	0
Roof surface	7	0	22	0	0	0
Seats	2	0	4	0	8	(8)
Seat belts	36	0	30	0	50	(8)
Other occupants	3	0	4	0	0	0
Floor & toe pan	13	(2)	0	0	0	0
Exterior contacts	9	(3)	11	(4)	0	0
Non-contact	41	0	41	0	33	0
Other	4	0.0	7	(4)	0	0
Average/Occupant	**2.2**	**(0.1)**	**2.1**	**(0.1)**	**1.1**	**(0.2)**

Figures for ALL contacts refer to the percentage of injured occupants who made contact with that particular vehicle component. Figures in parenthesis show the percentage of injured occupants for whom contact with that source resulted in a severe injury (AIS>2).

Front-left passengers had a similar pattern of injury sources to drivers, but with a marked increase in roof-surface contacts (22%). None of these contact sources caused serious injury to front-left passengers, the main source of severe injury being exterior contacts (4%). Rear-seat occupants recorded contacts with only seat belts (50%) and the sideglazing (17%), although 33% of them sustained non-contact injuries such as whiplash.

Table 4.13 shows the major differences in contact points for drivers of the three vehicle types were the instrument panel (over-representation of vans & 4WDs), the steering wheel (over-representation of 4WDs), the door panel (over-representation of utilities), seat belts (under-representation of vans), floor/toe pan (over-representation of vans), and non-contact sources (over-representation of utilities). Further, the contacts made by van drivers resulted in more severe injuries (particularly contacts with the instrument panel, exterior objects and the floor/toe pan) by comparison with driver contacts in the other two vehicle types.

Table 4.13 Points of Contact for Injured Drivers by Vehicle Type

POINTS OF CONTACTS	UTILITES		VANS		4WD	
	(n=35)		(n=39)		(n=42)	
	ALL %	(AIS>2) (%)	ALL %	(AIS>2) (%)	ALL %	(AIS>2) (%)
Windscreen/header	11	0	5	0	10	0
Steering wheel	23	0	18	0	36	0
Steering column	9	0	10	0	2	0
Instrument panel	17	(3)	51	(8)	33	(2)
Console	6	0	3	0	0	0
Pillar	9	(3)	3	0	0	0
Sideglaze	11	0	10	(3)	10	0
Door panel	20	(3)	13	0	10	0
Roof surface	9	0	0	0	12	0
Seats	3	0	3	0	0	0
Seat belts	37	0	31	0	41	0
Other occupants	0	0	5	0	0	0
Floor & toe pan	11	0	26	(5)	2	0
Exterior contacts	9	(3)	8	(8)	10	0
Non-contact	49	0	41	0	36	0
Other	6	0	5	0	2	0
Average/Occupant	**2.3**	**(0.1)**	**2.3**	**(0.3)**	**2**	**(0.02)**

Figures for ALL contacts refer to the percentage of injured occupants who made contact with that particular vehicle component. Figures in parenthesis show the percentage of injured occupants for whom contact with that source resulted in a severe injury (AIS>2).

4.5 INJURY/CONTACT SOURCE ANALYSES

In scoring injuries and points of contact, where there were multiple injury/source combinations for each occupant (e.g., two head injuries from the steering wheel), only the most severe injury/ contact source was scored. However, multiple scoring of injuries and points of contact for each occupant was allowed, providing they were unique injury-source combinations (e.g., two head injuries, one from the steering wheel and another from the instrument panel).

Injury/contact-source analyses are presented for the three main seating positions, namely drivers, front-left passengers, and rear seat passengers (Tables 4.14 - 4.16) and for drivers in the three vehicle types, namely utilities, vans and 4WDs (Tables 4.17 - 4.19). No analyses were attempted by seat belt wearing status because of the small number of unrestrained occupants observed in this study. For each of these tables non-contact injuries to the spine are typically whiplash injuries caused by crash forces, and non-contact injuries to the upper limbs are lacerations caused by flying glass.

Table 4.14 Body Region by Contact Source Analysis for ALL Injuries and Severe Injuries (AIS>2) for the 116 Drivers involved in ALL Collisions

BODY REGION / CONTACT SOURCE	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	Other Injury	TOTAL
Windscreen & header	2	3	1			6					12 (0)
Steering wheel	3	10	4	3	1	10	3				34 (0)
Steering column							7				7 (0)
Instrument panel	1 (1)	1	1 (1)	3 (2)	3 (1)	7	24 (2)	17 (2)			57 (9)
Console						1	1	1			3 (0)
Pillars			1 (1)			3					4 (1)
Side glazing	3 (1)	3				6					12 (1)
Door panel			2 (1)		3	6	3	1	[illegible]		18 (1)
Roof surface	4	2				1			3		10 (0)
Seats							1		1		2 (0)
Seat belts			20	8	6	13	1		4		54 (0)
Other occupant	1	1									2 (0)
Floor								13 (2)			13 (2)
Exterior	3 (3)	3 (1)	2 (1)			6 (1)	1	1	1		17 (6)
Non-contact	6	4	1		1	10		3	[illegible]		48 (0)
Other/ unknown	6	2	1 (1)	1		13 (1)	2		4	1	30 (2)
TOTAL	29 (5)	29 (1)	35 (5)	15 (2)	15 (1)	62 (2)	43 (2)	36 (4)	38 (0)	1 (0)	323 (22)

TOP row figures in each cell are the injury/source contact rates per 100 injured occupants for all injuries. Those in PARENTHESIS are the contact rates per 100 occupants for severe injuries (AIS>2). Multiple injuries are included where separate injury sources were involved.

Table 4.15 Body Region by Contact Source Analysis for ALL Injuries and Severe Injuries (AIS>2) for the 27 Front-Left Passengers involved in ALL Collisions

CONTACT SOURCE \ BODY REGION	**Head**	Face	**Chest**	**Abdomen**	**Pelvis**	Upper Limb	**Thigh & Knee**	Lower Leg	**Spine**	TOTAL
Windscreen & header		7								7 (0)
Steering wheel										0 (0)
Steering column										0 (0)
Instrument panel	4				4	4	19	11		42 (0)
Console										0 (0)
Pillars						7				7 (0)
Side glazing	7	7				7				21 (0)
Door panel						11				11 (0)
Roof surface	15	4				4			7	30 (0)
Seats		4								4 (0)
Seat belts			26	7	7	15	4			59 (0)
Other occupant	4	4								8 (0)
Floor										0 (0)
Exterior	4 (4)	4					4	4		16 (4)
Non-contact	7	4				7	7	7	15	47 (0)
Other/ unknown	4	4	4 (4)	4 (4)		11	4		4	35 (8)
TOTAL	45 (4)	38 (0)	30 (4)	11 (4)	11 (0)	66 (0)	38 (0)	22 (0)	26 (0)	287 (12)

TOP row figures in each cell are the injury/source contact rates per 100 injured occupants for all injuries. Those in PARENTHESIS are the contact rates per 100 occupants for severe injuries (AIS>2). Multiple injuries are included where separate injury sources were involved.

Table 4.16 Body Region by Contact Source Analysis for ALL Injuries and Severe Injuries (AIS>2) for the 12 Rear Passengers involved in ALL Collisions

BODY REGION / CONTACT SOURCE	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	Other Injury	TOTAL
Windscreen & header											0 (0)
Steering wheel											0 (0)
Steering column											0 (0)
Instrument panel											0 (0)
Console											0 (0)
Pillars											0 (0)
Side glazing	17	8							8		33 (0)
Door panel											0 (0)
Roof surface											0 (0)
Seats					8		8 (8)				16 (8)
Seat belts		17	17 (8)	8		17			8		67 (8)
Other occupant											0 (0)
Floor											0 (0)
Exterior											0 (0)
Non-contact						17			17	8	42 (0)
Other/ unknown						17					17 (0)
TOTAL	17 (0)	25 (0)	17 (8)	8 (0)	8 (0)	51 (0)	8 (8)	0 (0)	33 (0)	8 (0)	175 (16)

TOP row figures in each cell are the injury/source contact rates per 100 injured occupants for all injuries. Those in PARENTHESIS are the contact rates per 100 occupants for severe injuries (AIS>2). Multiple injuries are included where separate injury sources were involved.

4.5.1 Seating Position

Drivers. Table 4.14 shows that the three most common injury/contact-source combinations for drivers were:

- thigh /knee with instrument panel (24%),
- chest with seat belts (20%),
- lower leg with instrument panel (17%).

Non-contact injuries to the spine were also significant (24%). For severe injuries (**AIS>2**), the notable injury/contact-source combinations for drivers were:

- head with exterior (3%),
- abdomen, thigh/knee and lower leg with instrument panel (2% ea.),
- lower leg with floor (2%).

The relatively low number of cases for front-left and rear seating positions was somewhat problematic in this study. However, these results are included for completeness. It should be stressed however that these findings are based on very small sample sizes (27 & 12 occupants respectively) and therefore likely to be somewhat unreliable.

Front-Left Passengers: Table 4.15 shows that the most common injury/contact-source combinations for front-left passengers were:

- chest with seat belts (26%),
- thigh /knee with instrument panel (19%),
- head with the roof surface (15%) and
- upper limbs with seat belts (15%).

Non-contact injuries to the spine for front-left passengers were also significant (15%). The only notable severe (AIS>2) injury/contact-source combination for front-left passengers was the head with an exterior source (4%)

Rear Passengers: Table 4.16 shows that the most common injury/contact source combinations for rear passengers were the face, chest and upper limbs with seat belt, head with side glazing and non-contact injuries to the spine and upper limbs (all 17% ea.). The only combinations resulting in severe injuries were thigh/knee with seats and chest with seat belts (8% ea).

Table 4.17 Body Region by Contact Source Analysis for ALL Injuries and Severe Injuries (AIS>2) for the 42 - 4WD Drivers involved in ALL Collisions

BODY REGION / CONTACT SOURCE	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & header		5	2			7				14 (0)
Steering wheel	2	17	7	2		14	5			47 (0)
Steering column							2			2 (0)
Instrument panel						5	26	14 (2)		45 (2)
Console										0 (0)
Pillars										0 (0)
Side glazing	2					10				12 (0)
Door panel			2		2	5	2			11 (0)
Roof surface	10	2							2	14 (0)
Seats										0 (0)
Seat belts			24	12	10	10	2		5	63 (0)
Other occupant										0 (0)
Floor								2		2 (0)
Exterior	2	2				7				11 (0)
Non-contact	5	2				10		5	24	46 (0)
Other/ unknown	7	2	2			17	2		2	32 (0)
TOTAL	28 (0)	30 (0)	37 (0)	14 (0)	12 (0)	85 (0)	39 (0)	21 (2)	33 (0)	299 (2)

TOP row figures in each cell are the injury/source contact rates per 100 injured occupants for all injuries. Those in PARENTHESIS are the contact rates per 100 occupants for severe injuries (AIS>2). Multiple injuries are included where separate injury sources were involved.

Table 4.18 Body Region by Contact Source Analysis for ALL Injuries and Severe Injuries (AIS>2) for the 35 - Utility Drivers involved in ALL Collisions

BODY REGION / CONTACT SOURCE	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	Other Injury	TOTAL
Windscreen & header	6	3				6					15 (0)
Steering wheel	3	11	3	6		6	3				32 (0)
Steering column							9				9 (0)
Instrument panel					3 (3)	9	14	6			32 (3)
Console						3	3				6 (0)
Pillars			3 (3)			9					12 (3)
Side glazing	6	6				3					15 (0)
Door panel			9 (3)		6	9	3				27 (3)
Roof surface	3	3				3			6		15 (0)
Seats									3		3 (0)
Seat belts			23	9	11	17					60 (0)
Other occupant											0 (0)
Floor								11			11 (0)
Exterior	3 (3)					6					9 (3)
Non-contact	6	6	3			11		3	[illegible]		55 (0)
Other/ unknown	3	3	3 (3)			11	3		6	3	32 (3)
TOTAL	30 (3)	32 (0)	44 (9)	15 (0)	20 (3)	93 (0)	35 (0)	20 (0)	41 (0)	3 (0)	333 (15)

TOP row figures in each cell are the injury/source contact rates per 100 injured occupants for all injuries. Those in PARENTHESIS are the contact rates per 100 occupants for severe injuries (AIS>2). Multiple injuries are included where separate injury sources were involved.

Table 4.19 Body Region by Contact Source Analysis for ALL Injuries and Severe Injuries (AIS>2) for the 39 - Van Drivers involved in ALL Collisions

BODY REGION / CONTACT SOURCE	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & header						5				5 (0)
Steering wheel	3	3	3	3	3	10	3			28 (0)
Steering column							10			10 (0)
Instrument panel	3 (3)	3	3 (3)	8 (5)	5	8	31 (5)	31 (3)		92 (19)
Console								3		3 (0)
Pillars						3				3 (0)
Side glazing	3 (3)	5				5				13 (3)
Door panel			3		3	5	5	3	3	22 (0)
Roof surface										0 (0)
Seats							3			3 (0)
Seat belts			13	3	3	13			8	40 (0)
Other occupant	3	3								6 (0)
Floor								26 (5)		26 (5)
Exterior	6 (5)	5 (3)	5 (3)			5 (3)	3	3	3	29 (14)
Non-contact	8	5				8			23	44 (0)
Other/ unknown	8			3		10 (3)			5	26 (3)
TOTAL	33 (11)	24 (3)	27 (6)	17 (5)	14 (0)	72 (6)	55 (5)	66 (8)	42 (0)	350 (44)

TOP row figures in each cell are the injury/source contact rates per 100 injured occupants for all injuries. Those in PARENTHESIS are the contact rates per 100 occupants for severe injuries (AIS>2) Multiple injuries are included where separate injury sources were involved.

4.5.2 Vehicle Type

The injury/source analyses by vehicle type were confined to drivers only so that these results were directly comparable.

4WDS: Table 4.17 shows that the most common injury/contact source combinations for drivers of 4WDs were:

- thigh and knee with instrument panel (24%),
- chest with seat belts (24%), and
- face with steering wheel (17%).

Drivers of 4WDs sustained a similar level of non-contact injuries (24%) as drivers of utes and vans (26% and 23%). There was only one serious injury recorded for drivers of 4WDs, that being a lower leg injury caused by contact with the instrument panel.

Utilities: Table 4.18 shows that the most common injury/contact-source combinations for drivers of utilities were:

- chest with seat belts (23%),
- upper limb with seat belts (17%), and
- thigh/knee with instrument panel (14%).

Non-contact injuries to the spine were significant for drivers of utilities (26%). Severe injury/ contact-source combinations for drivers of utilities were:

- head with exterior (3%),
- chest with pillars (3%),
- chest with door panel (3%), and
- pelvis with instrument panel (3%).

Vans: Table 4.19 shows that most common injury/contact source combinations for drivers of vans were:

- thigh/knee with instrument panel (31%),
- lower leg with instrument panel (31%), and
- lower leg with floor (26%).

Non-contact injuries were also notable for drivers of vans (23%). Severe injury/contact source combinations for drivers of vans included:

- thigh/knee with instrument panel (5%),
- lower leg with floor (5%),and
- abdomen with instrument panel (5%).

5. DISCUSSION AND RECOMMENDATIONS

This chapter attempts to bring together the findings from the literature review, the mass data analysis and the crashed vehicle study to provide a broad overview of the occupant protection issues for current generation 4WDs, utilities and vans in the Australian vehicle fleet.

5.1 CHARACTERISTICS OF THE SAMPLE

5.1.1 Seating Position

Drivers were highly over-represented amongst the occupants of these crashed vehicles, compared with findings for crashed passenger cars, which is probably due to the large proportion of 'driver-only' vans and utilities used for commercial purposes. Of special interest, the proportions of occupants in other seating positions in 4WDs (40%) approximated that for passenger cars (38%). It is likely that the findings of the Crashed Vehicle Study for seating positions other than the driver are not totally reliable, given the relatively small numbers of people observed in these seating positions.

5.1.2 Age and Sex of Driver

The majority of the drivers of crashed 4WDs, utilities and vans in this sample (and in the mass data bases) was aged 26-55 years. This probably reflects higher exposure of this age group as drivers of these vehicles.

Males, too, were over-represented as drivers of these vehicles, compared to passenger cars. Results from both the crashed vehicle file and the mass data analysis revealed about 75-85% of injured occupants of 4WDs, utilities and vans were males compared with about 60% for passenger cars (CR 95) and 68% for the Victorian population generally (Rogerson & Keall, 1990). Again, it is likely that these findings reflect exposure differences, rather than differences in predisposition to injury.

5.1.3 Crash Types

Frontal impacts comprised the majority (55%) of crash types in this sample similar to earlier findings for passenger car occupants (60% frontal). Frontal impacts appeared to be under-represented in the NSW casualty crash database, but this is because only head-on frontals are coded separately in the impact direction variable.

There were, however, subtle differences in crash type by vehicle type illustrated in both the mass data analyses and the crashed vehicle file. Rollovers were strongly over-represented in the crashed vehicle file by comparison with passenger car crashes, where 44% of 4WD crashes and a further 27% of utility crashes involved rollovers. The propensity for 4WDs to rollover was further supported in the analysis of casualty and fatal crashes on the mass databases where 54% of fatal 4WD crashes and 12% of casualty 4WD crashes involved rollovers (cf. 20% fatal and 3% casualty for passenger cars). These findings support the suggestion from available literature that 4WDs, and to a lesser extent utilities, are more likely to be involved in rollover crashes because of their high centre of gravity relative to wheel base. The rollover propensity might also be accentuated by the greater use of these vehicles in rural areas at higher speeds and on unsealed roads.

Vans, by comparison, were primarily involved in frontal crashes (70%) probably reflecting more urban use of these vehicles. Although forward control vans have been found previously to have a propensity to rollover (Rattenbury & Gloyns, 1990), this was not supported in the current sample of crashes among passenger and light commercial vans, nor in the samples of casualty and fatal crashes in the mass databases. Anecdotally, many of the vans inspected in the Crashed Vehicle File seemed to be relatively less damaged than the other vehicle types, suggesting that there might be a tendency to write these vehicles off at lower levels of damage in the event of a collision.

5.1.4 Restraint Use

Levels of restraint use, which primarily reflected driver usage, since the proportions of occupants in other seating positions was so small, were consistent with population wearing rates for drivers of around 95% as assessed by exposure surveys (Rogerson & Keall, 1990). The wearing rate of 98% reported for this sample may be a slight overestimation, since it does not take into account the 11% of drivers whose belt wearing status could not be determined with any certainty.

The previous passenger car study (Fildes et al., 1991) showed that unrestrained occupants were roughly THREE times over-represented in hospital admissions or fatalities, compared with population figures. The fact that this was not repeated in this study is probably partly a function of differences in entrance criteria (from person-based to vehicle-based) and the higher proportion of uninjured or minor injured occupants observed here as a consequence. It might also be in part because of the relatively small numbers of cases observed in this study.

5.1.5 Ejection and Entrapment

It is therefore difficult to draw definitive conclusions about the influence of seat-belt wearing or impact type or vehicle type on ejection and entrapment from this sample of vehicles because there were so few instances of unrestrained occupants. The low incidence of ejections could be explained by the high rates of seat-belt wearing observed in this sample, and the low incidence of entrapments by the fact that the sampling method selected low severity crashes with consequently less intrusions.

The mass data findings on entrapments indicated that in fatal crashes occupants of 4WDs were less likely to be trapped than occupants of vans and passenger cars. This trend was especially more marked in frontal crashes. These results could be partly explained by the stronger substructures of 4WD vehicles offering more resistance to intrusions and therefore entrapment in head-on crashes. However, in rollover crashes occupants of 4WDs were more likely to be ejected than passenger car or van occupants. This result may be partly due to lower belt-wearing rates reported among 4WD occupants, but also to a lack of roof strength in 4WD vehicles resulting in vertical or lateral roof intrusion or the roof sheeting being dislodged from the roof structure, both of which increase the likelihood of partial or full ejection (Rechnitzer & Lane, 1994).

The issue of entrapment and ejection is worthy of further investigation, particularly with regard to rollover crash configurations where 4WDs are particularly vulnerable. Unfortunately, the number of cases inspected in the crashed vehicle file was too small to draw any definitive conclusions on this issue.

5.1.6 Impact Velocity

The delta-V values for this sample of vehicles were lower than those observed in the crashed passenger car sample, again indicating relatively lower crash severity in the current sample.

Again, there were insufficient cases to compare those who were hospitalised or killed in these special purpose vehicles with the passenger car findings. Of particular note, however, 86% of delta-V and EBS values were equal to or below 48 km/h, the value specified in ADR69, the new dynamic standard for passenger cars. It should be remembered that almost all of these vehicles were involved in a crash where the vehicle was written-off, which cannot be considered a minor impact, although most were below the threshold resulting in injuries requiring hospitalisation.

5.2 VEHICLE INTEGRITY

Intrusions in the front seating area were mainly from the steering assembly, toe pan and instrument panel. This is consistent with the predominance of frontal crashes in the sample. It is difficult to make definitive statements about the pattern of rear seat intrusions as the number of vehicles with rear seats fitted was a much smaller subset of the total sample of vehicles. Nevertheless, the most common rear seat intrusions (i.e., roof and roof side rail) reveal a pattern consistent with the substantial number of rollovers in this sample. Similar patterns of front and rear intrusions were found in the sample of passenger car crashes, although these had more door panel intrusions as a result of more side impact configurations.

Four-wheel-drives had a greater incidence of intrusions to the roof, roof side rail, A-pillar and windscreen & header, consistent with their greater involvement in rollover crashes. Vans had substantially more intrusions of the toe pan and instrument panel confirming findings by Paix and others (1985) and FORS (1987) that earlier versions of these vehicles did not offer sufficient lower leg protection because of a lack of frontal crash structural components.

5.3 INJURIES

5.3.1 Degree of Casualty

Although the vehicles in the crashed vehicle file were mainly write-offs, the occupants of these vehicles were relatively uninjured in these crashes. Eighty-four percent of occupants received either no injuries or only minor injuries requiring medical attention. While this was not desirable in terms of examining patterns of injuries to occupants of these vehicles, it was necessary to ensure sufficient cases for the study, given the relatively smaller proportions of these special purpose vehicles on the road. Nevertheless, the findings do provide some valuable insights into patterns of injuries likely to be sustained in crashes and show that there is scope for occupant protection improvement in these vehicles.

In the relatively low severity crashes sampled in the current study, occupants of 4WDs and utilities were more likely than van occupants to sustain injuries requiring medical attention (65% cf. 58%). Given that 4WDs and utes were over-involved in rollover crashes (35% cf. 10% of vans) the injury difference provides limited support for the convention that these crash types are typically associated with more injurious outcomes (Fildes et al., 1991; Rechnitzer & Lane, 1994). This contention was further supported by the mass data analysis of serious rollover crashes (casualty and fatal) where occupants of 4WDs were more likely to be killed or hospitalised than occupants of passenger vans.

5.3.2 Body Regions Injured

A summary of the injury findings from the crashed vehicle file is presented in Table 5.1 below. Injuries to the upper limbs were the most frequent injury sustained by drivers of 4WDs, utes and vans alike. They were predominantly minor (3% or less had an AIS>2) and equally common among all seating positions and across the three vehicle types.

Severe head and chest injuries predominated above all others as principal cause of death for occupants of these vehicles in the FORS fatal file. Given the fact that a small sample of crash tests involving 4WDs and vans in the Australian New Car Assessment Program (1994) showed relatively high head and chest injury values, there is a suggestion that the current generation of these vehicles do not offer adequate protection, especially for the driver.

Head and chest injuries in the crashed vehicle file were relatively less frequent by comparison with the passenger car study (26-29% cf. 61%), no doubt influenced by the less severe entrance criteria. Non-severe spine/neck injuries (predominantly whiplash) were relatively common in these crashes, occurring to roughly one third of all injured drivers. However, severe spinal injuries were a notable feature of the injury pattern for occupants of 4WDs killed in rollover crashes in the FORS fatal file. This latter finding warrants further investigation.

The relatively high proportion of lower limb injuries (knee, thigh, lower leg and foot) among drivers of vans and the increased likelihood of severe injury to these regions was highlighted in this study. Davis (1986) reported a 27% higher rate of injury crashes among forward control passenger vans by comparison with passenger cars. Davis (1986) and Paix and others (1985) also found an increased propensity for lower limb injuries. Paix and others (1985) claimed that van crashes were more costly in terms of treatment costs and argued that existing standards were insufficient to ensure optimum protection; the findings from the current study confirm this.

Table 5.1 Summary of Injuries to Drivers by Vehicle type

	UTILITIES (N=35)	VANS (N=39)	4WD's (N=42)
Degree of casualty:			
Uninjured	22%	24%	13%
Medically treated	62%	59%	73%
Hospitalised	16%	14%	14%
Killed	-	3%	-
Average Injury Severity Score (ISS):	5 9	7.1	3 6
Most frequent body region injured (All AIS):	Upper limb (60%)	Upper Limb (54%)	Upper Limb (69%)
Most frequent contact source for injuries (All AIS):	Non-contact (ie., whiplash) (49%)	Instrument panel (51%)	Seat belt (41%)
Most frequent injury/contact source combination (All AIS):	Chest - seat belt (23%)	Thigh/knee - instrument panel (31%)	Chest - seat belt Thigh/knee - instrument panel (24% ea)

5.3.3 Injury Severity

The overall level of injury severity for this sample of crashes was quite low. The average number of serious injuries (AIS>2) per occupant was less than 1, the probability of sustaining a serious injury was only 20% (compared with 60% for the passenger car study and the average Injury Severity Score (based on the three highest AIS scores) was 5.2 (cf. 17.8 in the passenger car study). Collectively, the observed pattern of injured body regions and the various indices of injury severity, further highlight the relatively less severe nature of the crashes in this sample.

One exception, though, was van drivers who had, on average, higher injury severity scores and higher probability of sustaining a severe injury compared to both 4WD and Utility drivers.

The results suggest that even in crashes of only moderate severity, occupants of vans are still susceptible to serious (albeit, non-life threatening) injuries. The question of whether 4WDs and utes by comparison offer better or worse protection to occupants in crashes or greater severity cannot be argued on the basis of these findings.

5.3.4 Contact Sources

It is not surprising that the majority of contacts in the crashed vehicle file were with the instrument panel, seat belts and steering wheel, given that the majority of crashes were frontal. These components were also the most common contact sources reported for frontal crashes among passenger cars.

One unusual finding was the relatively high proportion of drivers who sustained injuries not directly attributable to any specific structural components (non-contacts accounted for 41% in this study, compared with only 25% in the passenger car study). It is possible that given the relatively minor nature of injuries sustained by occupants in these crashes, non-contact injuries such as whiplash were more discernible, whereas in the passenger car study such injuries were most likely masked by more serious injuries requiring hospitalisation. While these injuries are relatively minor (in terms of AIS), they are, nevertheless, painful injuries and costly to treat.

Contact sources for the three vehicle types were directly correlated with intrusions, with van drivers being strongly over-involved in contacts with the instrument panel and floor/toe pan and drivers of 4WDs and utilities being slightly over-involved in contacts with the roof surface.

5.3.5 Injury/Contact Source Combinations

This study was especially useful in being able to assign contact sources to each injury sustained by the occupants. For drivers generally, the most common injury/source combinations were thigh, knee and lower leg injuries (a small number of them severe) caused by contact with the instrument panel . This can be explained by the high proportion of frontal crashes and suggests that the floor and lower structures are not optimal for occupants of these vehicles.

In addition, there were a number of chest injuries (albeit not usually severe) caused by the seat belt itself. This pattern is consistent with the passenger car study where a relatively high proportion of seat belt induced injuries were found. While such injuries are likely to be less severe than those for unrestrained occupants, these results indicate the scope for additional improvement in seat belt systems as well as improvements in seat design in these special purpose vehicles.

Head contacts with the steering wheel were much less prevalent among drivers in these crashes than in the sample of passenger car crashes (3% cf. 19%). However, this is also likely to be a function of the lower crash severity in this study. Drivers of 4WDs and utes had more face injuries from the steering wheel and chest injuries from the seat belts, while van drivers had comparatively more thigh/knee and lower leg injuries from the instrument panel and floor. In particular, the proportions of lower leg injuries caused by contacting the instrument panel and floor among van drivers were more than double those for drivers of 4WDs and utes. Non-contacts were equally significant across the three vehicle types.

There was a slight indication of head and spine injuries (although not severe) from the roof surface for drivers of 4WDs and utes. This finding was interesting in the light of evidence suggesting that in more severe rollover crashes, roof crush is directly related to spinal chord injuries caused by the head 'locking-in' under the roof framing (Rechnitzer & Lane, 1994).

It was not possible to draw any reliable conclusions regarding injury contact combinations for front and rear passengers as the numbers in these seating positions were too small.

5.4 COUNTERMEASURES

A number of countermeasures seem to be suggested from these findings, many of which have already been suggested from the previous passenger car study, and these are discussed below.

5.4.1 Steering Assembly

The steering assembly has been shown to inflict a considerable number of minor (AIS < 2) injuries to drivers of these special purpose cars. This is in spite of the fact that most drivers (up to 98%) were properly restrained. There are a number of steering assembly countermeasures worthy of consideration. As these have been fully discussed in the passenger car study, they are only listed here for completeness.

- **PADDED STEERING WHEELS** - Heavily padded wheels and hubs to soften the impact force of a head, chest or abdomen contacting the rigid metal structure of the wheel would be a useful countermeasure for drivers involved in frontal crashes.
- **BELT TIGHTENERS** - Belt tighteners to reduce forward movement by the occupant and the risk of impact with the steering wheel are another potential countermeasure against these injuries.
- **SUPPLEMENTARY AIRBAGS** - A supplementary airbag to the existing 3-point seat belt restraint system to cushion or prevent impact between the front seat occupant and the steering wheel or instrument panel is another important potential countermeasure for front seat occupants in frontal crashes. While these are fast becoming a common feature on new model passenger cars in Australia, there is little evidence yet of their wide-spread use on 4WDs, vans and utilities.

5.4.2 Improved Restraint Systems

The need for improvements to existing seat belt systems was noted in CR 95 for passenger cars and again highlighted in the injury and contact source findings here. Possible improvements to existing seat belt systems are listed below.

- **BETTER SEAT BELT GEOMETRY** - Improved front seat belt geometry is necessary to ensure that belt alignment is optimal and to minimise submarining and belt related injuries. As noted previously, this could be achieved by attaching the lower anchor points of the belts on the seat, rather than on the floor and providing an adjustable D-ring on the B-pillar.

- **BELT TIGHTENERS** - Mechanical and electronic belt tightening devices have recently started to appear on some current generation passenger cars in this country and are an effective means of preventing occupant contact with the steering wheel and instrument panel. The wide-spread use of these devices beyond passenger cars is to be encouraged.

- **WEBBING CLAMPS** - Seat belt webbing clamps have also been developed to reduce the amount of webbing reel-out from the retractor after it has locked. Although these are not as effective as belt tighteners because they do not remove all webbing slack in the system, they are considerably simpler and cheaper than belt tighteners and may be able to be installed with less lead time than belt tighteners.

- **FRONT SEAT DESIGN** - Evidence from the Crashed Vehicle File showed that the design of the front seat in 4WDs, vans and utilities is not optimal for occupant protection. A number of seat design improvements discussed for passenger cars in CR 95 such as integral seat belts, a more inclined seat cushion angle, a solid, appropriately sloped seat pan (to reduce submarining), close fitting head restraints, and stronger structure, are still desirable features.

- **SEAT BELT STALKS** - Positioning seat belt anchor stalks on the side of the front seat can lead to a marked reduction in abdominal injuries from contacts with the seat belt buckle. While the stalk arrangement is clearly still preferred, it is possible to position these fittings away from occupant areas to reduce the risk of abdominal injury.

- **SEAT BELT INTERLOCKS** - The seat belt has repeatedly been shown to be very effective in preventing serious injuries to vehicle occupants. In spite of this, 6% of front seat and approximately 30 to 40% of rear seat occupants still do not wear seat belts in Australian cars. While the numbers of unrestrained were relatively low in this study, the need for a seat belt interlock should be examined to help reduce severe injury amongst these occupants.

- **OTHER BELT IMPROVEMENTS** - The width of the seat belt and the webbing stiffness are aspects of the belt itself which can have a bearing on the injuries sustained by occupants. While there are limitations in how much these features can be varied, there may be substantial improvements that could be made by further research in this area. There may also be scope to introduce load limiting devices, although the trade-off of greater forward movement would need to be carefully considered.

5.4.3 The Instrument Panel

The instrument panel assembly was a problem area for front seat occupants of all vehicle types in the current study. There are several possible countermeasures currently available to minimise or alleviate these injuries.

- **BETTER MATERIALS** - The use of better safety materials in the construction of instrument panels is one obvious injury countermeasure. The current trend is to use moulded plastics in instrument panel and console construction (and the covers surrounding the steering column and other lower leg regions) which are often brittle and disintegrate leaving sharp edges to contact. Sheet metal covers could offer better energy absorbing properties with less propensity to shatter.

- **IMPROVED PADDING** - As noted for passenger cars in CR 95, the need for improved padding or energy absorbing construction was noted for the door surfaces, A- and B-pillars, header rails, and some parts of the instrument panel to soften occupant contact in the event of a collision.
- **REDUCED PROTRUSIONS** - Protrusions of the lower or underneath regions of the instrument panel were not uncommon. Furthermore, there were a number of instances of intrusions of the fire wall and floor pan in many of these vehicles, especially forward control vans. These need to be reduced by improved structure, greater crumple space, etc.
- **KNEE BOLSTERS** - Knee bolsters as fitted to many American models as part of their airbag systems have been suggested previously as an effective means of reducing lower limb injuries and would also be worthwhile for these special purpose vehicles.

5.5 VEHICLE REGULATIONS

Special purpose vehicles such as 4WDs, vans and utilities are not currently subject to the full set of Australian Design Rules that apply to passenger cars and their derivatives. In particular, the only frontal crash requirement is for these vehicles to comply with ADR10/01 which specifies maximum steering column intrusion levels. Furthermore, there is no rollover requirement either for these vehicles or for passenger cars.

Given the increasing use of these vehicles for private use as an alternative to passenger cars, it could be argued that they should also be expected to provide similar levels of occupant protection as passenger cars. Thus, a strong case could be mounted for all these special purpose vehicle types (4WDs, utilities, and vans) to be similarly regulated. In particular, they should at least be required to meet the new dynamic frontal crash performance requirement ADR69 as well as side impact regulations, either current or proposed for the future. Given the preponderance of roll-overs among 4WD vehicles, it would seem worthwhile for these vehicles in particular to have to meet a roof strength requirement as well, although the form of this standard may require further consideration.

5.6 FURTHER RESEARCH AND DEVELOPMENT

5.6.1 Additional Cases

Data shortages and additional research topics were highlighted on a number of occasions during this research program. The inability of the data to provide reliable robust findings for other than front seat occupants was noted, and with the vehicle-based entrance requirements, there was a general lack of seriously injured occupants. Indeed, many of these injury data were often hampered by having only a few relevant cases on which to draw meaningful conclusions. The high rate of seat belt wearing compared to other injury based studies could simply be a function of the vehicle based entrance criterion and minimal number of cases examined.

The most urgent need, therefore, is for the continuation of the crashed vehicle inspection program for these special purpose vehicles to ensure sufficient cases for a robust analysis of the injury consequences for their occupants. The best way to achieve this would be with a structured sample with minimum quotas of hospitalised and fatal cases.

5.6.2 Cost-Effectiveness of Countermeasures

The cost-effectiveness and therefore priority ranking of countermeasures was outside the scope of this study. While it is possible to rank safety improvements in terms of the frequency of injury contact, this disregards the costs and likely effectiveness of many of these measures in reducing the incidence and severity of occupant injuries. Further research would be required to provide the information necessary to effectively allocate scarce resources.

5.6.3 Effects of Bull Bars

It had been hoped to collect details on the injurious effects of bull bars, commonly found on the front of many of these special purpose vehicles. Unfortunately, this proved to be too difficult to undertake at this time. A study of the injurious effects of bull bars could certainly be undertaken if sufficient resources were available. As most mass databases do not code whether or not bull bars were fitted on crashed vehicles, a follow-up case study, similar to the Crashed Vehicle File, would be required. It would be likely that these units would have their most injurious effect on a vehicle impacted in the side when the striking vehicle was fitted with a bull bar.

REFERENCES

Australian Bureau of Statistics (1976-1991) *Motor vehicle census, Australia.* Catalogue No. 9309. Canberra, Australia: ABS.

Agran, P.F, Castillo, D. & Winn, D.G. (1990) 'Childhood motor vehicle occupant injuries', *Amer J Dis Child, 144*:653-662.

Bucklew, P.A., Osler, T.M., Eidson, J.J., Clavenger, F.W., Olson, S.E. & Demaresk, G.B. (1992) 'Falls and ejection from pickup trucks', *Journal of Trauma 32*: 468-478.

Cameron, C., Finch, C. & Le, T. (1994) *Vehicle crashworthiness ratings: Victoria and NSW crashes during 1987-92. Summary report,* Report No. 55, Monash University Accident Research Centre.

Cromark, J.R., Schneider, D., & Blaisdell, D. (1990). 'Occupant kinematics and belt markings in crash tests with unrestrained and partially restrained test dummies'. *Proceedings of the 34th annual conference of the Association for the Advancement of Automotive Medicine,* pp 203-225.

Cunningham, J.W. & Wilson, F.R. (1989) 'Injury patterns for occupants of small trucks', *Accident Analysis & Prevention, 21(2),* pp 105-113.

Data Link Inc. (1988) Light truck and van occupant exposure severity. Unpublished NHTSA Technical Memorandum.

Davis, C.J. (1986) *Forward control van crashes involving frontal impact,* RN 4/86, Traffic Authority of NSW, Sydney, NSW.

Federal Office of Road Safety (1986), *Frontal impact on forward control vehicles,* Report OR 8, Federal Office of Road Safety, Department of Transport, Canberra.

Fildes, B.F., Lane, J.C., Lenard, J. & Vulcan, A.P. (1991). *Passenger cars and occupant injury,* Report CR 95, Monash University Accident Research Centre, Federal Office of Road Safety, Canberra.

Fildes, B.F., Lane, J.C., Lenard, J. & Vulcan, A.P (1994) *Passenger cars and occupant injury: Side impact crashes,* Report no CR 134, Monash University Accident Research Centre, Federal Office of Road Safety, Canberra.

Graham, A. & Taylor, R. (1994) *Measuring the success of Road Safety 2000: trends and targets,* Road Safety Review Conference, Roads & Traffic Authority, Sydney.

Hamar, B., King, W., Bolton, A. & Fine, P.R. (1991) 'Fatal incidents involving pickup trucks in Alabama', *Southern Medical Journal, 84*: pp. 349-354.

Higgins, R.K. & Seyer, K.A. (1995) *Review of occupant protection in light commercial, off-road and forward control passenger vehicles.* Department of Transport, Federal Office of Road Safety, Canberra, Report OR 17.

Hinch, J., Shadle, S. & Klein, T.M. (1992) *NHTSA rollover rule-making program. In Vehicle dynamics and rollover propensity research,* SAE SP-909, pp117-130.

Klein, T.M. (1994) 'Statistical analysis of vehicle rollover propensity and vehicle stability', *Auto & Traffic Safety, 1(2)*, pp 2-10.

Mengert, P., Salvatore, S., DiSario, R. & Walter, R. (1989) *Statistical estimation of rollover risk.* NHTSA, Report DOT-HS-807-446.

NCAP (1994), *Crash test report technical summary,* New Car Assessment Program, Sydney, Vol 1, No. 3.

Nelson, D.C. & Struebert, J.V. (1991) 'Effect of open backed vehicles on casualty rates: The case of Papua New Guinea', *Accident Analysis & Prevention, 23*, pp. 109-117.

Paix, B.R., Gibson, T.J. & McLean, A.J. *(1985) The safety of forward control passenger vehicles*, University of Adelaide, NH&MRC Road Accident Research Unit.

Partyka, S., Sikora, J., Surti, J. & Van Dyke, J. (1987) *Relative risk to car and light truck occupants*, SAE Paper 871093.

Rattenbury, S.J. & Gloyns, P.F. (1990) *Fatal accidents involving forward control vans, mini-buses and motor caravans in 1986.* TRRL Contract Report No 1350.

Rechnitzer, G. & Lane, J. (1994) *Rollover crash study - vehicle design and occupant injuries,* Report no. 65, Monash University Accident Research Centre, Melbourne.

Reinfurt, D.W., Stutts, J.C. & Hamilton, E.G. (1984) *'A further look at utility vehicle rollovers.* University of North Carolina Highway Safety Research Center.

Rogerson, P. & Keall, M. (1990) *Melbourne on-road exposure surves: 1984, 1985, 1986, 1988.* Report GR/90-5, VicRoads Research and Investigations, Australia.

Tong, T. & Teaford, P.A. (1989) 'Falls from pickup trucks during childhood', *Amer J Dis Child 143,* pp. 997-998

Woodward, G.A. & Bolte, R.G. (1990) 'Children riding in the back of pickup trucks', *Pediatrics, 86,* pp. 683-691.

Attachment 1

Details of Inspection Procedure

INSPECTION PROCEDURE FOR CRASHED VEHICLES

The inspection procedure for crashed vehicles divides naturally into six stages: (1) fully identifying and specifying the damaged vehicle, (2) describing the exterior body damage, (3) describing the interior (passenger compartment) damage, (4) reconstructing the injury mechanism, (5) compiling a photographic record, and (6) establishing a computer database for analysis.

1. IDENTIFICATION

The vehicle type is specified (a) by reference to its external badges, number plates, compliance plate, manufacturer's plate, emission control label, chassis number and registration label and (b) by direct observation of the car body, engine, undercarriage and interior.

2. EXTERIOR DAMAGE

Observations on the state of the doors and windows are generally routine. The two main types of glass (laminated and toughened) shatter differently, the fracture pattern thereby enabling identification. The setting of a broken side-window at impact (open or closed) is indicated by glass fragments left around the window frame and by the location of the winder mechanism within the door. Laminated glass normally reveals by its fracture pattern whether it was broken by deformation of its frame or by point contact (eg. a head or hand); in the case of toughened glass it is sometimes necessary to search for hair or skin fragments around the window frame, or other forensic evidence, to help assign the cause of damage.

The main aims of the remaining external damage observations are to record (a) the direction and area of application of the impact force and (b) the change in shape ("crush") of the crashed vehicle, especially as would be seen from overhead.

The region of direct contact, such as metal-to-metal contact between two cars, is usually indicated by the extent of crush, by sharp changes of shape of metallic components, by the relatively fine-grained texture of surface damage (eg. to sheet metal panels), and similar considerations.

The direction of the force applied to the vehicle during impact is often reflected in the residual deformation of structural components within the region of direct contact. In the case of an offset frontal, for example, the front corner making metal-to-metal contact with the other car may be crushed (a) directly back, or (b) back and into the engine compartment, or (c) back and to the outside of the original body line. Similarly, in the case of a side collision centred on the passenger compartment, the B-pillar may be pushed directly across the car, or across the car with a component of deformation to either the front or the back. This type of observation provides a physical basis for the assignment of the impact force direction to the clockface (ie. to the nearest 30 deg.). Scratch lines, the overall shape of body crush and various other discernible features may also be useful, however this assessment always requires an element of judgment and an awareness of numerous complexities.

The change in shape from original of the crashed vehicle is sketched and measured. The sketches are made over diagrams of a generic sedan viewed from its four sides and overhead. These sketches routinely include the vehicle's post-crash shape, the area of direct contact and direction of force, sheet metal buckling, secondary impacts, car body bowing, parts of the vehicle cut, damaged or removed after the crash, scratch lines, and notes relevant to the crash sequence or to the interpretation of the photographic record.

The crash damage measurements are intended in part to provide input to the CRASH3 program for calculating DELTA-V - the vehicle's change of velocity during impact (NHTSA 1986). This influences the measurement procedure and format in which the data is recorded. A typical case might run as follows:-

The car has suffered frontal damage. A horizontal 2m pole supported on two uprights is aligned with the undamaged rear bumper to serve as a zero reference line. A 5m measuring tape is laid on the ground alongside the car extending from the rear bumper line to (beyond) the front bumper. Readings are then taken of the rear axle-line, front axle-line and the front bumper corner. The original position of the front bumper is also marked off on the ground at this stage, this specification length having been determined from reference texts carried on site. Since the damage is severe, readings are also taken of the A, B and C pillars, the dashboard corner and the steering wheel hub in order to help subsequent estimates of interior damage and injury mechanisms. All the measurements on each side are taken without moving the tape, making it a one-person operation and minimizing measurement uncertainty.

The three-piece frame is then moved from the rear of the car to the original front bumper position, to serve now as a zero reference line for front-end crush. The crush profile is recorded by six measurements taken at equal distances (left to right) along the deformed surface of the car (i.e. crush is measured at six points along the car that were equally spaced before the accident). The crush profile is completed by recording the width of the overall damage field and of the direct contact sub-field, and by locating these fields within the damaged side - in this case the front end of the car. These measures again refer to pre-crash or original lengths. For example, if the front-end has been reduced to 80% of its original width and wholly damaged as a result of wrapping around a pole, the damage field is recorded as the original width. Sometimes this means that reference has to be made to similar undamaged cars, to an undamaged section of the same car, or to original specifications.

Finally, the damage is coded according to the Collision Deformation Classification (SAE J224 MAR80).

The procedure for a side collision varies slightly from the frontal case. The zero reference line for the measurement of crush is generally directly marked off by string or a 2m pole placed across the field of damage and aligned at its ends to undamaged sections of the car surface. For example, a damaged vehicle that had taken impact to its left doors might have its crush profile taken relative to a string attached or aligned to the left side A and C pillars. This method largely avoids the incorporation of the body structure 'bowing' into the crush profile.

The case of a rollover or of other non-two-dimensional impact cannot be analysed by the CRASH3 model, so measurements are made as the case dictates, with the aim of having as accurate passenger compartment intrusion information as possible.

3. INTERIOR DAMAGE

A main aim of the internal damage observations is to record the change of shape and intrusions into the passenger compartment. Sketches are drawn over printed diagrams of various views of a generic passenger compartment. These sketches routinely include (i) outlines of the vehicle's internal shape at mid, lower and upper sections, (ii) identification of intruding components and the magnitude and direction of the extent of intrusion, (iii) steering wheel movement, (iv) components cut, damaged or removed after impact, and (v) notes on items of special interest or importance. Intrusion magnitudes (and other movements) are usually estimated on site, using a tape measure, by either judging original positions or by comparing measurements with a similar undamaged car or an undamaged section of the same car.

Special attention is given during the internal damage inspection to the steering assembly, seats and seat belts. Beyond a routine description of these components (tilt column, bucket seats, retractable belts etc.) the seats and seat belts are checked for mechanical or performance failure, and both the movement of the steering column relative to its mount at the dashboard and the deformation of the steering wheel rim are measured.

One important task is to ascertain whether the seatbelts in the car were in use during the accident. A belt system that has been loaded can leave a variety of signs:

- The surfaces of the tongue (latchplate) touching the webbing often appear to be scratched or abraded in a manner never occurring by normal wear and tear. This sign varies from being barely discernible under magnification to being grossly visible at a cursory glance.
- Similar damage may be observed on the D-ring typically mounted on the upper B-pillar.
- The webbing which in use lies in the vicinity of the D-ring or tongue may be marked by scummy deposits, by discolouration, by a change in surface texture and reflectivity due to fibre flattening or abrasion, or by fibre damage as if by the generation of surface heat.
- The interior trim down the B-pillar may be fractured or dislodged by the tightening and straightening of the webbing directed from the D-ring to the retractor.
- Other components may be damaged by loading of the seat belt system, including the latch and surrounding parts, and the webbing and surrounding parts in the vicinity of the lower outboard anchor.
- Blood and glass fragments or similar may be present over the full length of the webbing (or over only that part of the webbing that is exposed while fully retracted).

Occasionally useful circumstantial evidence is available, for example, the webbing may have beencut during rescue, indicating that the rescue team found it in use.

Sometimes the crash forces on a belt system are not sufficient to leave any discernible signs. In practice this means that it is generally easier to prove (by inspection) that a belt was worn than to prove that it was not.

4. INJURY MECHANISM

The final part of the vehicle inspection involves reconstructing how the occupant's injuries occurred.

Normal practice is to obtain the injury details before conducting the inspection. This gives focus to the examination, enabling maximum confidence in the reconstruction to be built up in minimum time. The signs of occupant contact can be extremely subtle and the mechanisms of injury can be elusive or complex - it helps to know whether one is searching for the explanation of a broken nose or of a broken ankle!

As an initial working assumption, the direction of the occupant's inertial movement relative to the vehicle during the accident sequence may be assumed to be opposite to the direction of the applied impact force. Given the occupant's seating position and likelihood of seat belt use, this suggests where to look for signs of contact; in the case of a left side impact, for example, one searches initially to the left of the injured occupant. A simple aid to gaining some feel for the situation is to sit in the same position as the patient - if possible with the seat belt tensioned by the body to its position at full load.

Signs of occupant contact vary greatly: clothing fibres, strands of hair and flakes of skin can be found on the contacted components; movement, damage or deformation of components around the car interior may be plainly due to forces originating from within the car and acting oppositely to the direction of the impact force; intrusion may be so great as to make contact inevitable; component surfaces may be smeared, brushed, discoloured or abraded by the contact.

Notes on the signs of occupant contact are recorded over diagrams of a generic vehicle interior, with the emphasis heavily on injury-causing contacts. A judgment of confidence level is also assigned to each suggested contact point.

In the absence of specific evidence, a degree of inference can be involved in the assignment of injury-causing contact points. For example, an unbelted driver might be known to have hit his head on the windscreen and his knees on the lower dash; his bilateral rib fractures are then plausibly attributed to steering wheel contact, even though no forensic evidence or rim deformation is apparent. This type of judgment, to a greater or lesser degree, runs through the reconstruction of how some injuries occur.

One situation of particular difficulty and frequency is the case of a belted driver suffering sternum or rib fractures. It is not always easy to distinguish seat belt pressure from steering wheel contact as the injuring force. Routine procedure in this case, if possible, is to line up the belt webbing into its position of full load (as described above) and to measure the distance from the sternum to the steering wheel hub. If appropriate, placing one's knees into a shattered lower dashboard and stretching one's head toward a point of known contact gives some impression of the likelihood of steering wheel contact, always bearing in mind the probable role of webbing stretch, elastic rebound of the steering assembly, occupant's height and weight, and various other considerations. It may be most plausible, in this and several other common situations, to attribute the injury to a combination of forces.

There are normally more injuries that injury-causing contact points. It saves time at inspection to have already grouped the injuries according to their likely common cause. The broken nose, cut lip, chipped tooth and fractured jaw, for example, probably arose in the same way. These injury groups are transcribed from the hospital report onto a page bearing several views of the human body; explanatory notes on the origin and application of forces on the body likely to have generated these injuries are then made as part of the inspection process.

5. PHOTOGRAPHIC RECORD

After the field notes are completed, around twenty to thirty photographs are taken of the crashed vehicle. An unexceptional case has a rough balance between interior and exterior shots - unusual or interesting features naturally draw special attention.

6. COMPUTER RECORD

Much of the information gathered from the patient interview, injury description and vehicle inspection is converted to (mostly) numeric code, generating about 650-1000 characters on computer for each occupant (depending on the number of injuries). Information such as name, address and registration number are specifically not included to protect confidentiality. The code is mostly derived from the NASS format (NHTSA 1989).

The CRASH3 program is used to compute impact velocity from residual crush measurements. Statistical analysis is undertaken on SPSS software.

Attachment 2

Consent Forms and Occupant Injury Form

MONASH UNIVERSITY

AUSTRALIA

ACCIDENT RESEARCH CENTRE
Director, Professor A P Vulcan

Dear ____________________,

Thank you for talking to us recently and agreeing to help us in our vehicle safety research. The Accident Research Centre at Monash University is currently engaged in a study of how vehicles perform in accidents. This work is aimed at making our vehicles and roads safer for all Australians

This work requires us to examine vehicles involved in road crashes to determine how various parts of the vehicle behave in real accidents and compare these findings with the sorts of injuries people like yourself have suffered as a result of the crash.

To do this, we need your co-operation. We would like to talk to you about the crash you were recently involved in and any injuries you may have sustained from the crash We would also like to see if you can recall which parts of the vehicle caused your injuries.

If you were treated in a hospital after the crash, we would also like to look at your medical record file at this hospital.

The information we collect is for **research purposes only** and will be treated in strictest confidence. We do not intend discussing any aspect of our findings with either the police, your insurance company or any other party to the crash. We may need to inspect any other vehicle involved in the collision as well but only for the purpose of examining the damage sustained in the crash. We will not seek to participate in any legal action over the crash

At the end of our investigations, we will condense all the individual cases of information into anonymous sets of data without names and addresses. Hence, your confidentiality is further safeguarded. At the end of our research, our report will highlight aspects of car design that require further safety improvements.

We have enclosed a consent form for you to sign, agreeing to participate in this important study and, where appropriate, authorising us to obtain details about your injuries from the hospital, or other medical practitioner where you were treated. Please sign and date the attached form indicating that you are willing to participate in the study. Our nurse, Sister Kate Edwards-Coghill will contact you shortly to talk to you.

I hope you have made a swift recovery from your injuries and that you have fully recovered from the effects of the accident.

Yours sincerely,

Peter Vulcan

Professor Peter Vulcan,

Director.

Should you have any complaint concerning the manner in which this research project is conducted, please do not hesitate to inform the researchers in person or you may prefer to contact the Standing Committee on Ethics in Research on Humans, University Secretariat, Monash University.

CLAYTON, VICTORIA, 3168 AUSTRALIA FAX (61) (3) 905 4363 TELEPHONE (03) 905 4371 IDD +61 3 905 4371

Dear ______________________

CONSENT TO BE INTERVIEWED

I have read through and understand this letter and I HEREBY CONSENT to officers of the Monash University Accident Research Centre interviewing me about the circumstances of the collision I was recently involved in and consulting my hospital records if appropriate.

Signature ____

Please print full name ____

Dated this ____________ day of ____________________ 19

Treating Hospital ____

Treating Doctor ____

(Doctor's Address) ____

____Telephone________________

Would you please sign this form and return it to the Monash University Accident Research Centre as soon as possible. Thank you for your co-operation with this important research.

Should you have any complaint concerning the manner in which this research project is conducted, please do not hesitate to inform the researchers in person or you may prefer to contact the Standing Committee on Ethics in Research on Humans, University Secretariat, Monash University.

OCCUPANT PROTECTION PROJECT

MEDICAL REPORT FORM

Reg. No.	Case No.

Date of interview
Date of birth

OCCUPANT DETAILS	
Name	
Address	
Telephone	UR/Coroner No

CRASH DETAILS	
Location	
Date	Time
Police Station	Officer
Ambulance Type	Case No.

OTHER VEHICLE	
Make/Model	
Owner/Driver	
Address	
Telephone	Reg. No.
Passenger name Telephone number	
Treating hospital or GP	

Monash University Accident Research Centre

MEDICAL REPORT FORM

Case No.

ACCIDENT CIRCUMSTANCES	
Vehicle Make/Model	
Seat Position	Seatbelt Use
Description	
Evasive Action (steering, braking)	
Vehicle-A Speed (pre-impact, impact)	
Vehicle-B Speed	Driving Experience
Weather	Light
Trailer	*Heavy luggage/cargo*
Fuel Level	*Fuel Spillage*
Fire	*Windows Open*
Trapped	
Ejected	
Exit from Vehicle	

MEDICAL REPORT FORM

INJURY DESCRIPTION	
Injury	Source
Bruises	
Abrasions	
Lacerations (sutures required)	
Fractures	
Loss of consciousness	
Relevant Prior Injuries	
Treatment Level	Duration of Treatment

MEDICAL REPORT FORM

OCCUPANT DETAILS	
Age	Sex *Pregnant*
Height	Weight

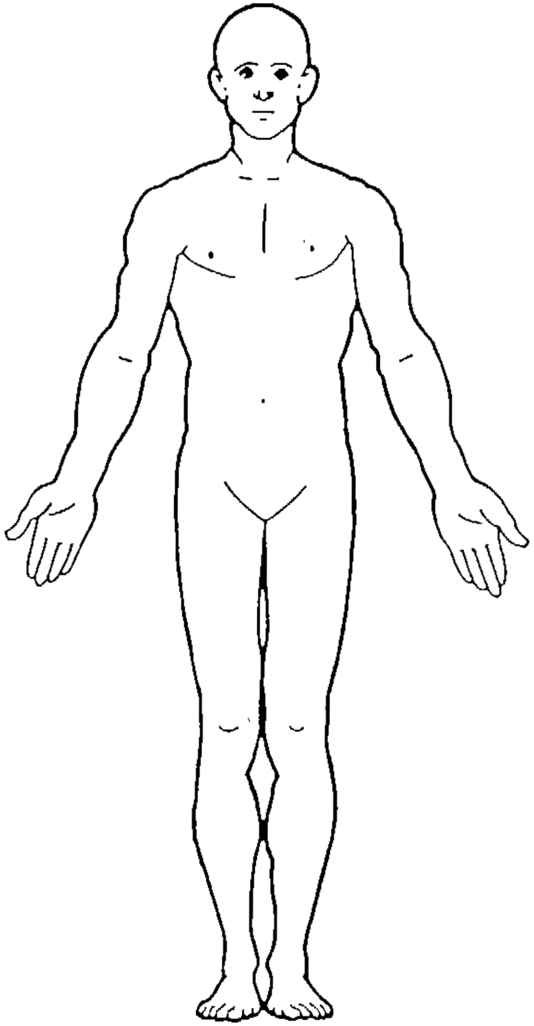
OTHER OCCUPANTS

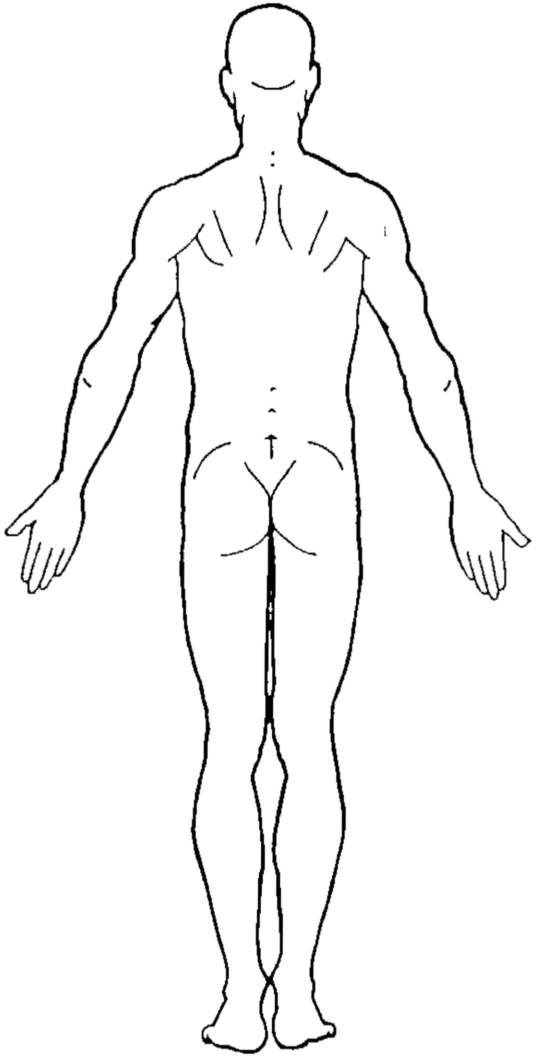
MEDICAL REPORT FORM

FINAL INJURY CODING		
AIS Code	NASS Code	Description

OFFICIAL INJURY DATA—SOFT TISSUE INJURIES

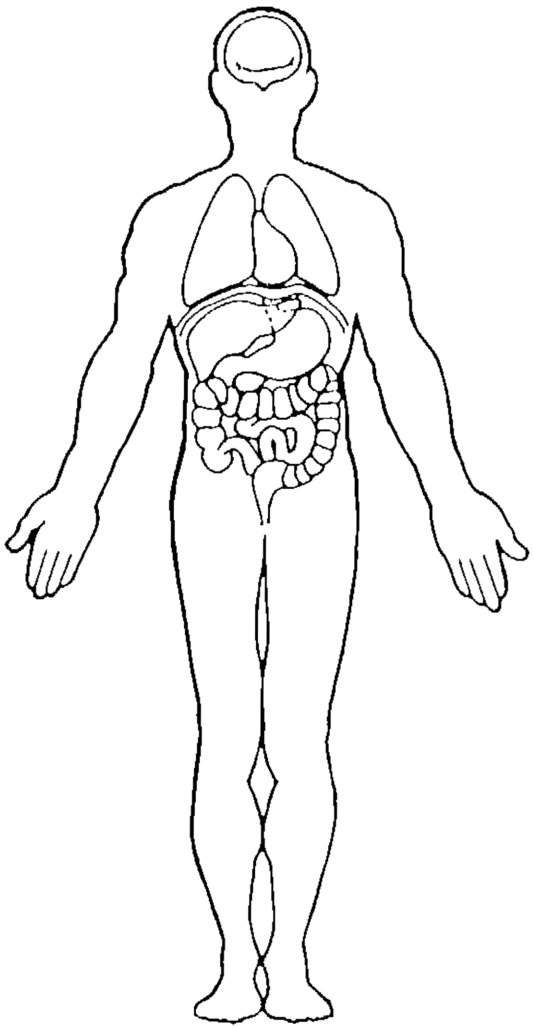
Indicate the *Location, Lesion, Detail* (size, depth, fracture type, head injury clinical signs and neurological deficits), and *Source* of all injuries indicated by official sources (or from PAR or other unofficial sources if medical records and interviewee data are unavailable.)

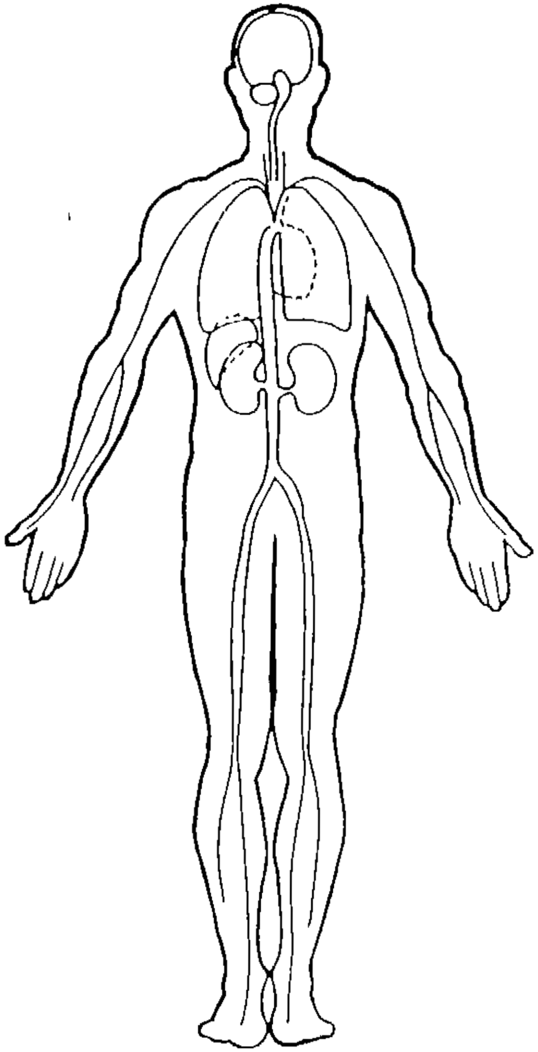




OFFICIAL INJURY DATA—INTERNAL INJURIES

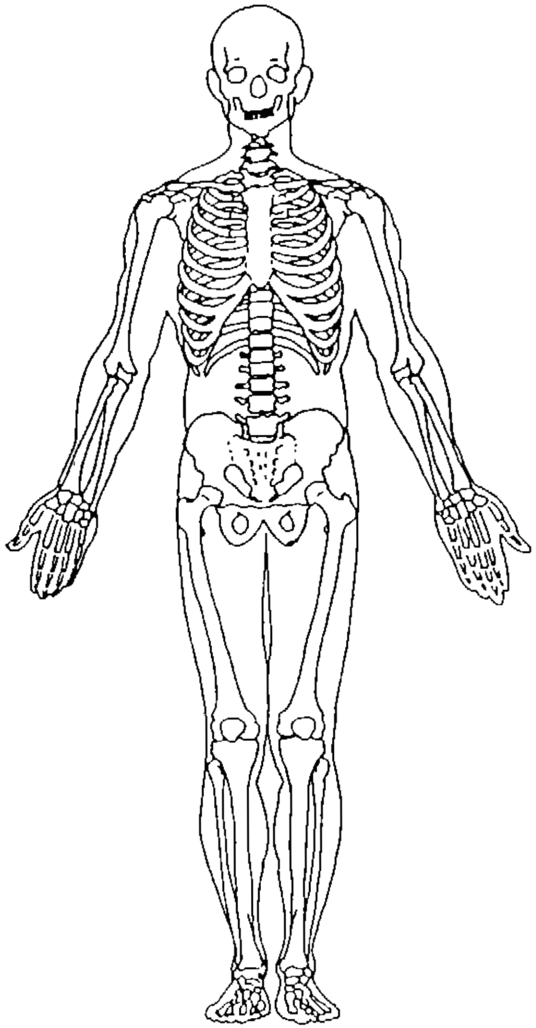
Indicate the *Location, Lesion, Detail* (size, depth, fracture type, head injury clinical signs and neurological deficits), and *Source* of all injuries indicated by official sources (or from PAR or other unofficial sources if medical records and interviewee data are unavailable.)

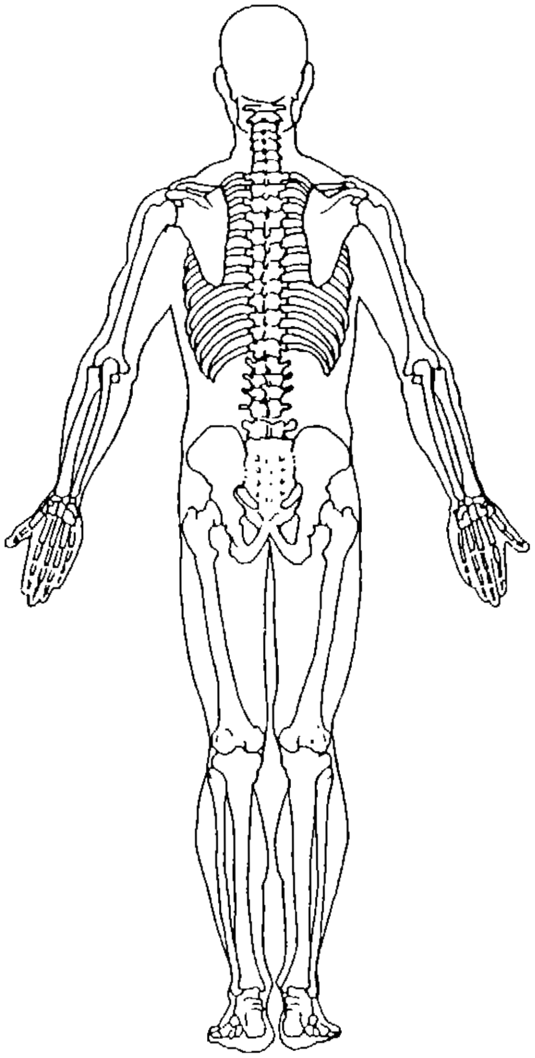




OFFICIAL INJURY DATA—SKELETAL INJURIES

Indicate the *Location, Lesion, Detail* (size, depth, fracture type, head injury clinical signs and neurological deficits), and *Source* of all injuries indicated by official sources (or from PAR or other unofficial sources if medical records and interviewee data are unavailable.)





OCCUPANT INJURY FORM

CASE NUMBER ____________ PATIENT'S NAME ______________________________

HOSPITAL NUMBER ________________ UR NUMBER ________________________

INJURY DATA

Record below the actual injuries sustained by this occupant that were identified from the official and unofficial data sources. Remember not to double count an injury just because it was identified from two different sources. If greater than twenty injuries have been documented, encode the balance on the Occupant Injury Supplement.

		O.I.C.–A.I.S.								
	Source of Injury Data	Body Region	Aspect	Lesion	System Organ	A.I.S. Severity	Injury Source	Injury Source Confidence Level	Direct/ Indirect Injury	Occupant Area Intrusion No.
1st	5. ___	6. ___	7. ___	8. ___	9. ___	10. ___	11. ___ ___	12. ___	13. ___	14. ___ ___
2nd	15. ___	16. ___	17. ___	18. ___	19. ___	20. ___	21. ___ ___	22. ___	23. ___	24. ___ ___
3rd	25. ___	26. ___	27. ___	28. ___	29. ___	30. ___	31. ___ ___	32. ___	33. ___	34. ___ ___
4th	35. ___	36. ___	37. ___	38. ___	39. ___	40. ___	41. ___ ___	42. ___	43. ___	44. ___ ___
5th	45. ___	46. ___	47. ___	48. ___	49. ___	50. ___	51. ___ ___	52. ___	53. ___	54. ___ ___
6th	55. ___	56. ___	57. ___	58. ___	59. ___	60. ___	61. ___ ___	62. ___	63. ___	64. ___ ___
7th	65. ___	66. ___	67. ___	68. ___	69. ___	70. ___	71. ___ ___	72. ___	73. ___	74. ___ ___
8th	75. ___	76. ___	77. ___	78. ___	79. ___	80. ___	81. ___ ___	82. ___	83. ___	84. ___ ___
9th	85. ___	86. ___	87. ___	88. ___	89. ___	90. ___	91. ___ ___	92. ___	93. ___	94. ___ ___
10th	95. ___	96. ___	97. ___	98. ___	99. ___	100. ___	101. ___ ___	102. ___	103. ___	104. ___ ___
11th	105. ___	106. ___	107. ___	108. ___	109. ___	110. ___	111. ___ ___	112. ___	113. ___	114. ___ ___
12th	115. ___	116. ___	117. ___	118. ___	119. ___	120. ___	121. ___ ___	122. ___	123. ___	124. ___ ___
13th	125. ___	126. ___	127. ___	128. ___	129. ___	130. ___	131. ___ ___	132. ___	133. ___	134. ___ ___
14th	135. ___	136. ___	137. ___	138. ___	139. ___	140. ___	141. ___ ___	142. ___	143. ___	144. ___ ___
15th	145. ___	146. ___	147. ___	148. ___	149. ___	150. ___	151. ___ ___	152. ___	153. ___	154. ___ ___
16th	155. ___	156. ___	157. ___	158. ___	159. ___	160. ___	161. ___ ___	162. ___	163. ___	164. ___ ___
17th	165. ___	166. ___	167. ___	168. ___	169. ___	170. ___	171. ___ ___	172. ___	173. ___	174. ___ ___
18th	175. ___	176. ___	177. ___	178. ___	179. ___	180. ___	181. ___ ___	182. ___	183 ___	184. ___ ___
19th	185. ___	186. ___	187. ___	188. ___	189. ___	190. ___	191. ___ ___	192. ___	193. ___	194. ___ ___
20th	195. ___	196. ___	197. ___	198. ___	199. ___	200. ___	201. ___ ___	202 ___	203 ___	204. ___ ___

Derived with appreciation from the National Accident Sampling System, National Highway & Safety Administration, US Department of Transportation.

SOURCE OF INJURY DATA

OFFICIAL

(1) Autopsy records with or without hospital medical records
(2) Hospital medical records other than emergency room (eg. discharge summary)
(3) Emergency room records only (including associated X-rays or other lab reports)
(4) Private physician, walk-in or emergency clinic

UNOFFICIAL

(5) Lay coroner report
(6) E.M.S. personnel
(7) Interviewee
(8) Other source (specify):

(9) Police

INJURY SOURCE

FRONT

(01) Windshield
(02) Mirror
(03) Sunvisor
(04) Steering wheel rim
(05) Steering wheel hub/spoke
(06) Steering wheel (combination of codes 04 and 05)
(07) Steering column, transmission selector lever, other attachment
(08) Add-on equipment (e.g., CB, tape deck, air conditioner)
(09) Left instrument panel and below
(10) Center instrument panel and below
(11) Right instrument panel and below
(12) Glove compartment door
(13) Knee bolster
(14) Windshield including one or more of the following: front header, A-pillar, instrument panel, mirror, or steering assembly (driver side only)
(15) Windshield including one or more of the following: front header, A-pillar, instrument panel, or mirror (passenger side only)
(16) Other front object (specify)

LEFT SIDE

(20) Left side interior surface, excluding hardware or armrests
(21) Left side hardware or armrest
(22) Left A pillar
(23) Left B pillar
(24) Other left pillar (specify):

(25) Left side window glass or frame
(26) Left side window glass including one or more of the following: frame, window sill, A-pillar, B-pillar, or roof side rail
(27) Other left side object (specify)

RIGHT SIDE

(30) Right side interior surface, excluding hardware or armrests
(31) Right side hardware or armrest
(32) Right A pillar
(33) Right B pillar
(34) Other right pillar (specify):

(35) Right side window glass or frame
(36) Right side window glass including one or more of the following: frame, window sill, A-pillar, B-pillar, roof side rail
(37) Other right side object (specify):

INTERIOR

(40) Seat, back support
(41) Belt restraint webbing/buckle
(42) Belt restraint B-pillar attachment point
(43) Other restraint system component (specify)

(44) Head restraint system
(45) Air cushion
(46) Other occupants (specify):

(47) Interior loose objects
(48) Child safety seat (specify):

(49) Other interior object (specify):

ROOF

(50) Front header
(51) Rear header
(52) Roof left side rail
(53) Roof right side rail
(54) Roof or convertible top

FLOOR

(56) Floor including toe pan
(57) Floor or console mounted transmission lever, including console
(58) Parking brake handle
(59) Foot controls including parking brake

REAR

(60) Backlight (rear window)
(61) Backlight storage rack, door, etc.
(62) Other rear object (specify):

EXTERIOR OF OCCUPANT'S VEHICLE

(65) Hood
(66) Outside hardware (e.g., outside mirror, antenna)
(67) Other exterior surface or tires (specify):

(68) Unknown exterior objects

EXTERIOR OF OTHER MOTOR VEHICLE

(70) Front bumper
(71) Hood edge
(72) Other front of vehicle (specify)

(73) Hood
(74) Hood ornament
(75) Windshield, roof rail, A-pillar
(76) Side surface
(77) Side mirrors
(78) Other side protrusions (specify):

(79) Rear surface
(80) Undercarriage
(81) Tires and wheels
(82) Other exterior of other motor vehicle (specify):

(83) Unknown exterior of other motor vehicle

OTHER VEHICLE OR OBJECT IN THE ENVIRONMENT

(84) Ground
(85) Other vehicle or object (specify)

(86) Unknown vehicle or object

NONCONTACT INJURY

(90) Fire in vehicle
(91) Flying glass
(92) Other noncontact injury source (specify)

(97) Injured, unknown source

INJURY SOURCE CONFIDENCE LEVEL

(1) Certain
(2) Probable
(3) Possible
(9) Unknown

DIRECT/INDIRECT INJURY

(1) Direct contact injury
(2) Indirect contact injury
(3) Noncontact injury
(7) Injured, unknown source

OCCUPANT INJURY CLASSIFICATION

O.I.C. Body Region

(M)	Abdomen
(Q)	Ankle–foot
(A)	Arm (upper)
(B)	Back–thoracolumbar spine
(C)	Chest
(E)	Elbow
(F)	Face
(R)	Forearm
(H)	Head–skull
(U)	Injured, unknown region
(K)	Knee
(L)	Leg (lower)
(Y)	Lower limb(s) (whole or unknown part)
(N)	Neck–cervical spine
(P)	Pelvic–hip
(S)	Shoulder
(T)	Thigh
(X)	Upper limb(s) (whole or unknown part)
(O)	Whole body
(W)	Wrist–hand

Aspect of Injury

(A)	Anterior–front
(C)	Central
(I)	Inferior–lower
(U)	Injured, unknown aspect
(L)	Left
(P)	Posterior–back
(R)	Right
(S)	Superior–upper
(W)	Whole region

Lesion

(A)	Abrasion
(M)	Amputation
(V)	Avulsion
(B)	Burn
(K)	Concussion
(C)	Contusion
(N)	Crush
(G)	Detachment, separation
(D)	Dislocation
(F)	Fracture
(Z)	Fracture and dislocation
(U)	Injured, unknown lesion
(L)	Laceration
(O)	Other
(P)	Perforation, puncture
(R)	Rupture
(S)	Sprain
(T)	Strain
(E)	Total severance, transection

System/Organ

(W)	All systems in region
(A)	Arteries–veins
(B)	Brain
(D)	Digestive
(E)	Ears
(O)	Eye
(H)	Heart
(U)	Injured, unknown system
(I)	Integumentary
(J)	Joints
(K)	Kidneys
(L)	Liver
(M)	Muscles
(N)	Nervous system
(P)	Pulmonary–lungs
(R)	Respiratory
(S)	Skeletal
(C)	Spinal cord
(Q)	Spleen
(T)	Thyroid, other endocrine gla
(G)	Urogenital
(V)	Vertebrae

Abbreviated Injury Scale

(1)	Minor injury
(2)	Moderate injury
(3)	Serious injury
(4)	Severe injury
(5)	Critical injury
(6)	Maximum (untreatable)
(7)	Injured, unknown severity

Attachment 3

The (NASS) Vehicle Inspection Forms

U.S. Department of Transportation
National Highway Traffic Safety Administration

GENERAL VEHICLE FORM

NATIONAL ACCIDENT SAMPLING SYSTEM
CRASHWORTHINESS DATA SYSTEM

1. Primary Sampling Unit Number ___ ___

2. Case Number—Stratum ___ ___ ___ ___

3. Vehicle Number ___ ___

VEHICLE IDENTIFICATION

4. Vehicle Model Year ___ ___
Code the last two digits of the model year
(99) Unknown

5. Vehicle Make (specify): ___ ___

____

Applicable codes are found in your NASS CDS Data Collection, Coding, and Editing Manual.
(99) Unknown

6. Vehicle Model (specify): ___ ___ ___

____

Applicable codes are found in your NASS CDS Data Collection, Coding, and Editing Manual.
(999) Unknown

7. Body Type ___ ___
Note: Applicable codes are found on the back of this page.

8. Vehicle Identification Number

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Left justify; Slash zeros and letter Z (0 and Z)
No VIN—Code all zeros
Unknown—Code all nine's

OFFICIAL RECORDS

9. Police Reported Vehicle Disposition ___
(0) Not towed due to vehicle damage
(1) Towed due to vehicle damage
(9) Unknown

10. Police Reported Travel Speed ___ ___

Code to the nearest mph (NOTE: 00 means less than 0.5 mph)
(97) 96.5 mph and above
(99) Unknown

11. Police Reported Alcohol or Drug Presence ___
(0) Neither alcohol nor drugs present
(1) Yes (alcohol present)
(2) Yes (drugs present)
(3) Yes (alcohol and drugs present)
(4) Yes (alcohol or drugs present—specifics unknown)
(7) Not reported
(8) No driver present
(9) Unknown

12. Alcohol Test Result for Driver ___ ___
Code actual value (decimal implied before first digit—0.xx)
(95) Test refused
(96) None given
(97) AC test performed, results unknown
(98) No driver present
(99) Unknown

Source ______________________

ACCIDENT RELATED

13. Speed Limit ___ ___
(00) No statutory limit
Code posted or statutory speed limit
(99) Unknown

14. Attempted Avoidance Maneuver ___ ___
(00) No impact
(01) No avoidance actions
(02) Braking (no lockup)
(03) Braking (lockup)
(04) Braking (lockup unknown)
(05) Releasing brakes
(06) Steering left
(07) Steering right
(08) Braking and steering left
(09) Braking and steering right
(10) Accelerating
(11) Accelerating and steering left
(12) Accelerating and steering right
(98) Other action (specify):

____

(99) Unknown

15. Accident Type ___ ___
Applicable codes may be found on the back of page two of this field form
(00) No impact
Code the number of the diagram that best describes the accident circumstance
(98) Other accident type (specify):

____

(99) Unknown

****** STOP HERE IF GV07 DOES NOT EQUAL 01-49 ******

HS Form 435
1/88

OCCUPANT RELATED

16. Driver Presence in Vehicle ___
(0) Driver not present
(1) Driver present
(9) Unknown

17. Number of Occupants This Vehicle ___ ___
(00-96) Code actual number of occupants for this vehicle
(97) 97 or more
(99) Unknown

18. Number of Occupant Forms Submitted ___ ___

VEHICLE WEIGHT ITEMS

19. Vehicle Curb Weight ___ ___, ___ **0 0**
___Code weight to nearest 100 pounds.
(000) Less than 50 pounds
(135) 13,500 lbs or more
(999) Unknown

Source: ______________________

20. Vehicle Cargo Weight ___ ___ **0 0**
___Code weight to nearest 100 pounds.
(00) Less than 50 pounds
(97) 9,650 lbs or more
(99) Unknown

RECONSTRUCTION DATA

21. Towed Trailing Unit ___
(0) No towed unit
(1) Yes—towed trailing unit
(9) Unknown

22. Documentation of Trajectory Data for This Vehicle ___
(0) No
(1) Yes

23. Post Collision Condition of Tree or Pole (for Highest Delta V) ___
(0) Not collision (for highest delta V) with tree or pole
(1) Not damaged
(2) Cracked/sheared
(3) Tilted <45 degrees
(4) Tilted ≥45 degrees
(5) Uprooted tree
(6) Separated pole from base
(7) Pole replaced
(8) Other (specify): ______________________
(9) Unknown

24. Rollover ___
(0) No rollover (no overturning)

Rollover (primarily about the longitudinal axis)
(1) Rollover, 1 quarter turn only
(2) Rollover, 2 quarter turns
(3) Rollover, 3 quarter turns
(4) Rollover, 4 or more quarter turns (specify): ______________________

(5) Rollover—end-over-end (i.e., primarily about the lateral axis)
(9) Rollover (overturn), details unknown

OVERRIDE/UNDERRIDE (THIS VEHICLE)

25. Front Override/Underride (this vehicle) ___

26. Rear Override/Underride (this vehicle) ___

(0) No override/underride, or not an end-to-end impact

Override (see specific CDC)
(1) 1st CDC
(2) 2nd CDC
(3) Other not automated CDC (specify): ______________________

Underride (see specific CDC)
(4) 1st CDC
(5) 2nd CDC
(6) Other not automated CDC (specify): ______________________

(7) Medium/heavy truck override
(9) Unknown

HEADING ANGLE AT IMPACT FOR HIGHEST DELTA V

Values: (000)-(359) Code actual value
(997) Noncollision
(998) Impact with object
(999) Unknown

27. Heading Angle for This Vehicle ___ ___ ___

28. Heading Angle for Other Vehicle ___ ___ ___

9. Basis for Total Delta V (Highest) ___

Delta V Calculated
(1) CRASH program—damage only routine
(2) CRASH program—damage and trajectory routine
(3) Missing vehicle algorithm

Delta V Not Calculated
(4) At least one vehicle (which may be this vehicle) is beyond the scope of an acceptable reconstruction program, regardless of collision conditions.

(5) All vehicles within scope (CDC applicable) of CRASH program but one of the collision conditions is beyond the scope of the CRASH program or other acceptable reconstruction techniques, regardless of adequacy of damage data.

(6) All vehicle and collision conditions are within scope of one of the acceptable reconstruction programs, but there is insufficient data available.

COMPUTER GENERATED DELTA V

Secondary Highest

0. **Total Delta V** ___ ___

___ **Nearest mph** ___

(NOTE: 00 means less than 0.5 mph)
(97) 96.5 mph and above
(99) Unknown

1. **Longitudinal Component of Delta V** + ___ ___

___ **Nearest mph** ___

(NOTE. __00 means greater than −0.5 and less than +0.5 mph)
(±97) ±96.5 mph and above
(__ 99) Unknown

Secondary Highest

32. Lateral Component of Delta V ± ___ ___

___ Nearest mph ___

(NOTE· __00 means greater than −0.5 and less than −0.5 mph)
(±97) ±96.5 mph and above
(__ 99) Unknown

33. Energy Absorption ___ ___ ___, ___ **0 0**

___ Nearest 100 foot-lbs ___

(NOTE: 0000 means less than 50 Foot-Lbs)
(9997) 999,650 foot-lbs or more
(9999) Unknown

34. **Confidence in Reconstruction Program Results (for Highest Delta V)** ___
(0) No reconstruction
(1) Collision fits model—results appear reasonable
(2) Collision fits model—results appear high
(3) Collision fits model—results appear low
(4) Borderline reconstruction—results appear reasonable

35. **Type of Vehicle Inspection** ___
(0) No Inspection
(1) Complete inspection
(2) Partial inspection (specify):

___

***** STOP HERE IF THE CDS APPLICABLE *****
VEHICLE WAS NOT INSPECTED

U.S. Department of Transportation
National Highway Traffic Safety Administration

EXTERIOR VEHICLE FORM

NATIONAL ACCIDENT SAMPLING SYSTE
CRASHWORTHINESS DATA SYSTE

1. Primary Sampling Unit Number ___ ___
2. Case Number—Stratum ___ ___ ___ ___
3. Vehicle Number ___ ___

VEHICLE IDENTIFICATION

VIN ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ Model Year ________

Vehicle Make (specify): ____________ Vehicle Model (specify): ____________

LOCATOR

Locate the end of the damage with respect to the vehicle longitudinal center line or bumper corner for end impacts or an undamaged axle for side impacts.

Specific Impact No.	Location of Direct Damage	Location of Field L

CRUSH PROFILE

NOTES: Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, etc.) and label adjustments (e.g., free space).

Measure and document on the vehicle diagram the location of maximum crush.

Measure C1 to C6 from driver to passenger side in front or rear impacts and rear to front in side impacts.

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

Use as many lines/columns as necessary to describe each damage profile.

Specific Impact Number	Plane of C-Measurements-	Direct Damage		Field L	$-C_1$	C_2	C_3	C_4	C_5	C_6	$\pm D$
		Width (CDC)	Max Crush								

HS Form 435A
1/88

ational Accident Sampling System—Crashworthiness Data System: Exterior Vehicle Form 2

VEHICLE DAMAGE SKETCH

TIRE—WHEEL DAMAGE

a. Rotation physically restricted	b. Tire deflated
RF ____	RF ____
LF ____	LF ____
RR ____	RR ____
LR ____	LR ____

(1) Yes (2) No (8) NA (9) Unk.

TYPE OF TRANSMISSION

☐ Manual ☐ Automatic

ORIGINAL SPECIFICATIONS

Wheelbase ____________
Overall Length ____________
Maximum Width ____________
Curb Weight ____________
Average Track ____________
Front Overhang ____________
Rear Overhang ____________
Engine Size: cyl./ displ. ____________
Undeformed End Width ____________

WHEEL STEER ANGLES

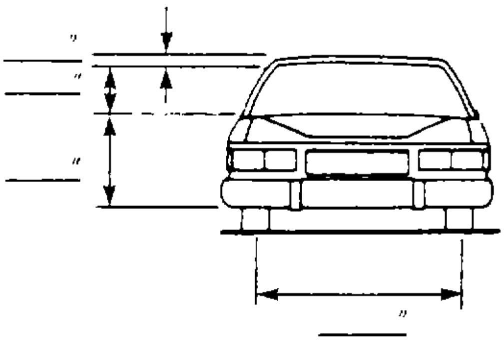
(For locked front wheels or displaced rear axles only)

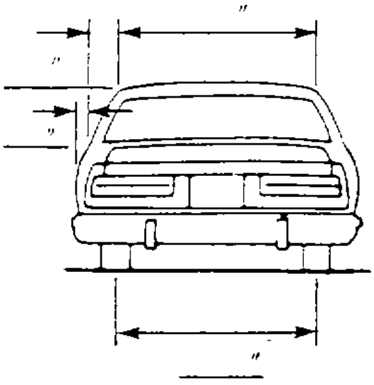
RF ± ______ °
LF ± ______ °
RR ± ______ °
LR ± ______ °
Within ±5 degrees

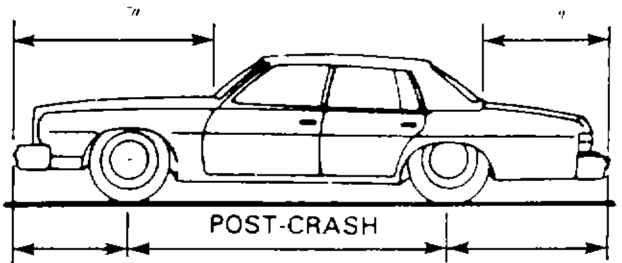
DRIVE WHEELS

☐ FWD ☐ RWD ☐ 4WD

Approximate Cargo Weight ____________

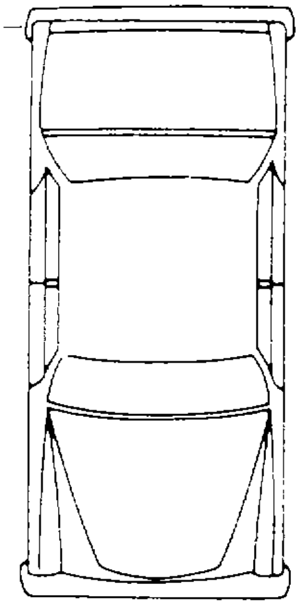


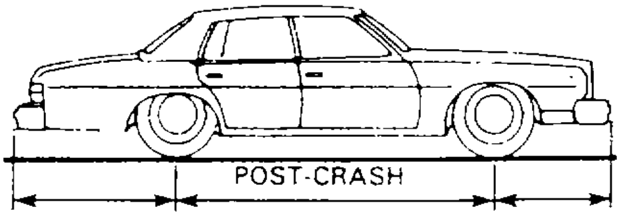




Bumper corner ______″ ______″ ______″ Bumper corner

Stringline ______″ ______″ Stringline





Bumper corner ______″ ______″ ______″ Bumper corner

Stringline ______″ ______″ Stringline

NOTES. Sketch new perimeter and cross hatch direct damage and single hatch induced damage on all views. Annotate observations which might be useful in reconstructing the accident (e.g., grass in tire bead, direction of striations, scuff on sidewall, etc.) If pulling trailer, sketch type of trailer and damage received on the back of this page

Annotate any damage caused by extrication such as component removal by torching, prying, or hydraulic shears

CDC WORKSHEET

CODES FOR OBJECT CONTACTED

01-30 — Vehicle Number

Noncollision
- (31) Overturn — rollover
- (32) Fire or explosion
- (33) Jackknife
- (34) Other intraunit damage (specify): ____________________
- (35) Noncollision injury
- (38) Other noncollision (specify): ____________________
- (39) Noncollision — details unknown

Collision with Fixed Object
- (41) Tree (≤4 inches in diameter)
- (42) Tree (>4 inches in diameter)
- (43) Shrubbery or bush
- (44) Embankment
- (45) Breakaway pole or post (any diameter)

Nonbreakaway Pole or Post
- (50) Pole or post (≤4 inches in diameter)
- (51) Pole or post (>4 but ≤12 inches in diameter)
- (52) Pole or post (>12 inches in diameter)
- (53) Pole or post (diameter unknown)
- (54) Concrete traffic barrier
- (55) Impact attenuator
- (56) Other traffic barrier (specify): ____________________
- (57) Fence
- (58) Wall
- (59) Building
- (60) Ditch or Culvert
- (61) Ground
- (62) Fire hydrant
- (63) Curb
- (64) Bridge
- (68) Other fixed object (specify): ____________________
- (69) Unknown fixed object

Collision With Nonfixed Object
- (71) Motor vehicle not in transport
- (72) Pedestrian
- (73) Cyclist or cycle
- (74) Other nonmotorist or conveyance (specify): ____________________
- (75) Vehicle occupant
- (76) Animal
- (77) Train
- (78) Trailer, disconnected in transport
- (88) Other nonfixed object (specify): ____________________
- (89) Unknown nonfixed object
- (98) Other event (specify): ____________________
- (99) Unknown event or object

DEFORMATION CLASSIFICATION BY EVENT NUMBER

Accident Event Sequence Number	Object Contacted	(1) (2) Direction of Force (degrees)	Incremental Value of Shift	(3) Deformation Location	(4) Specific Longitudinal or Lateral Location	(5) Specific Vertical or Lateral Location	(6) Type of Damage Distribution	(7) Deformation Extent

COLLISION DEFORMATION CLASSIFICATION

Accident Event Sequence Number	Object Contacted	(1) (2) Direction of Force	(3) Deformation Location	(4) Specific Longitudinal or Lateral Location	(5) Specific Vertical or Lateral Location	(6) Type of Damage Distribution	(7) Deformation Extent
HIGHEST DELTA "V"							
4. __ __	5. __ __	6. __ __	7. __	8. __	9. __	10. __	11. __ __
Second Highest Delta "V"							
12. __ __	13. __ __	14. __ __	15. __	16. __	17. __	18. __	19. __ __

CRUSH PROFILE

(The crush profile for the damage described in the CDC(s) above should be documented in the appropriate space below. ALL MEASUREMENTS ARE IN INCHES.)

HIGHEST DELTA "V"

20. L	21. C1	C2	C3	C4	C5	C6	22. + − D
__ __ __	__ __	__ __	__ __	__ __	__ __	__ __	+ − __ __ __ __

Second Highest Delta "V"

23. L	24. C1	C2	C3	C4	C5	C6	25. − − D
__ __ __	__ __	__ __	__ __	__ __	__ __	__ __	+ − __ __ __ __

26. Are CDCs Documented but Not Coded on The Automated File
(0) No
(1) Yes

27. Researcher's Assessment of Vehicle Disposition
(0) Not towed due to vehicle damage
(1) Towed due to vehicle damage
(9) Unknown

28. Original Wheelbase __ __ __ __ Code to the nearest tenth of an inch
(9999) Unknown

*****STOP HERE IF THE CDS APPLICABLE*****
VEHICLE WAS NOT TOWED (I.E., GV09 = 0 OR 9)

U.S. Department of Transportation
National Highway Traffic Safety Administration

INTERIOR VEHICLE FORM

NATIONAL ACCIDENT SAMPLING SYSTEM
CRASHWORTHINESS DATA SYSTEM

1. Primary Sampling Unit Number __ __

2. Case Number—Stratum __ __ __ __

3. Vehicle Number __ __

INTEGRITY

4. Passenger Compartment Integrity __ __

(00) No integrity loss

Yes, Integrity Was Lost Through
(01) Windshield
(02) Door (side)
(03) Door/hatch (rear)
(04) Roof
(05) Roof glass
(06) Side window
(07) Rear window
(08) Roof and roof glass
(09) Windshield and door (side)
(10) Windshield and roof
(11) Side and rear window
(98) Other combination of above (specify):

____

(99) Unknown

Door, Tailgate Or Hatch Opening

5. LF __ 6. RF __ 7. LR __ 8. RR __ 9. TG/H __

(0) No door/gate/hatch
(1) Door/gate/hatch remained closed and operational
(2) Door/gate/hatch came open during collision
(3) Door/gate/hatch jammed shut
(8) Other (specify):

____

(9) Unknown

Damage/Failure Associated with Door, Tailgate or Hatch Opening in Collision. If IV05-IV09 ≠ 2, Then Code 0.

10. LF __ 11. RF __ 12. LR __ 13. RR __ 14. TG/H __

(0) No door/gate/hatch or door not opened

Door, Tailgate, or Hatch Came Open During Collision
(1) Door operational (no damage)
(2) Latch/striker failure due to damage
(3) Hinge failure due to damage
(4) Door structure failure due to damage
(5) Door support (i.e., pillar, sill, roof side rail, etc.) failure due to damage
(6) Latch/striker and hinge failure due to damage
(8) Other failure (specify):

____

(9) Unknown

GLAZING

Glazing Damage from Impact Forces

15. WS __ 16. LF __ 17. RF __ 18. LR __ 19. RR __

20. BL __ 21. Roof __ 22. Other __

(0) No glazing damage from impact forces
(2) Glazing in place and cracked from impact forces
(3) Glazing in place and holed from impact forces
(4) Glazing out-of-place (cracked or not) and not holed from impact forces
(5) Glazing out-of-place and holed from impact forces
(6) Glazing disintegrated from impact forces
(7) Glazing removed prior to accident
(8) No glazing
(9) Unknown if damaged

Glazing Damage from Occupant Contact

23. WS __ 24. LF __ 25. RF __ 26. LR __ 27. RR __

28. BL __ 29. Roof __ 30. Other __

(0) No occupant contact to glazing or no glazing
(1) Glazing contacted by occupant but no glazing damage
(2) Glazing in place and cracked by occupant contact
(3) Glazing in place and holed by occupant contact
(4) Glazing out-of-place (cracked or not) by occupant contact and not holed by occupant contact
(5) Glazing out-of-place by occupant contact and holed by occupant contact
(6) Glazing disintegrated by occupant contact
(9) Unknown if contacted by occupant

If No Glazing Damage *And* No Occupant Contact or No Glazing, Then Code IV 31 Through IV 46 As 0

Type of Window/Windshield Glazing

31. WS __ 32. LF __ 33. RF __ 34. LR __ 35. RR __

36. BL __ 37. Roof __ 38. Other __

(0) No glazing contact and no damage, or no glazing
(1) AS-1 – Laminated
(2) AS-2 – Tempered
(3) AS-3 – Tempered-tinted
(4) AS-14 – Glass/Plastic
(8) Other (specify):

____

(9) Unknown

Window Precrash Glazing Status

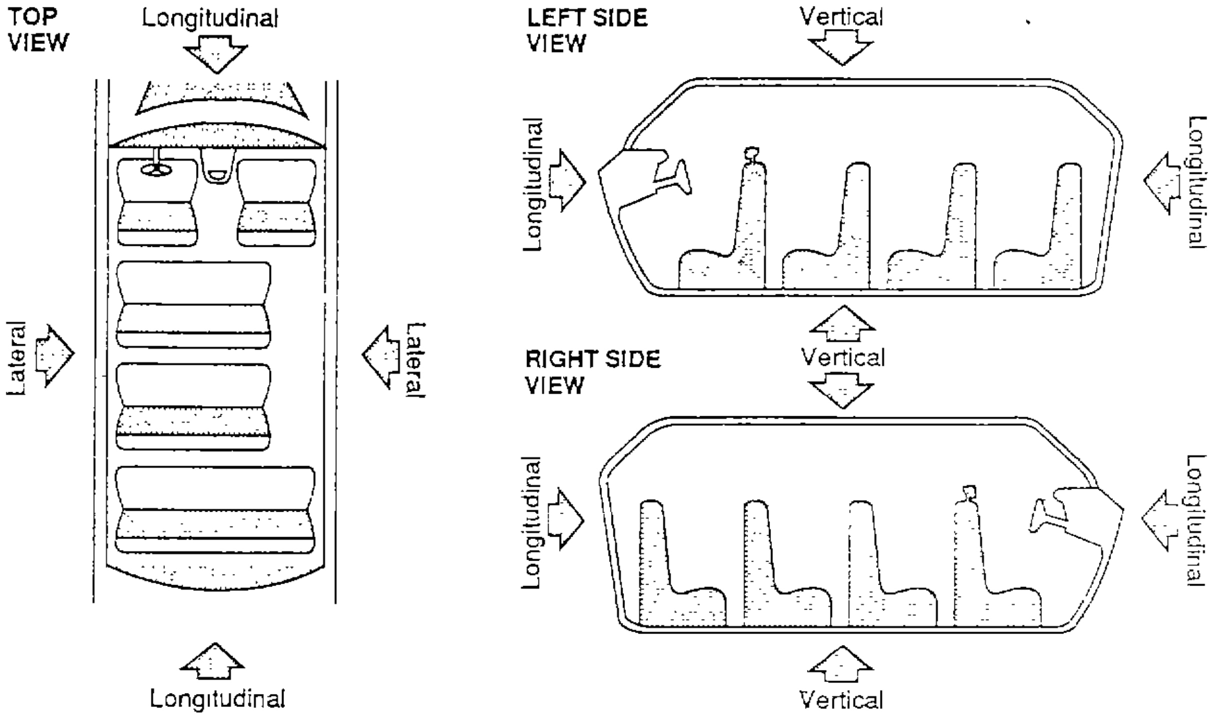
39. WS __ 40. LF __ 41. RF __ 42. LR __ 43. RR __

44. BL __ 45. Roof __ 46. Other __

(0) No glazing contact and no damage, or no glazing
(1) Fixed
(2) Closed
(3) Partially opened
(4) Fully opened
(9) Unknown

HS Form 435C
1/88

INTRUSION WORK SHEET



INTRUDED COMPONENT	LOCATION OF INTRUSION	DOMINANT CRUSH DIRECTION	COMPARISON VALUE	–	INTRUDED VALUE	=	INTRUSION
				–		=	
				–		=	
				–		=	
				–		=	
				–		=	
				–		=	
				–		=	
				–		=	
				–		=	
				–		=	
				–		=	
				–		=	
				–		=	
				–		=	
				–		=	

OCCUPANT AREA INTRUSION

Note: If no intrusions, leave variables IV 47-IV 86 blank.

	Location of Intrusion	Intruding Component	Magnitude of Intrusion	Dominant Crush Direction
1st	47.______	48.______	49.____	50.____
2nd	51.______	52.______	53.____	54.____
3rd	55.______	56.______	57.____	58.____
4th	59.______	60.______	61.____	62.____
5th	63.______	64.______	65.____	66.____
6th	67.______	68.______	69.____	70.____
7th	71.______	72.______	73.____	74.____
8th	75.______	76.______	77.____	78.____
9th	79.______	80.______	81.____	82.____
10th	83.______	84.______	85.____	86.____

LOCATION OF INTRUSION

Front Seat
- (11) Left
- (12) Middle
- (13) Right

Second Seat
- (21) Left
- (22) Middle
- (23) Right

Third Seat
- (31) Left
- (32) Middle
- (33) Right

Fourth Seat
- (41) Left
- (42) Middle
- (43) Right

(98) Other enclosed area (specify): ______________________

(99) Unknown

INTRUDING COMPONENT

Interior Components
- (01) Steering assembly
- (02) Instrument panel left
- (03) Instrument panel center
- (04) Instrument panel right
- (05) Toe pan
- (06) A-pillar
- (07) B-pillar
- (08) C-pillar
- (09) D-pillar
- (10) Door panel
- (11) Side panel/kickpanel
- (12) Roof (or convertible top)
- (13) Roof side rail
- (14) Windshield
- (15) Windshield header
- (16) Window frame
- (17) Floor pan
- (18) Backlight header
- (19) Front seat back
- (20) Second seat back
- (21) Third seat back
- (22) Fourth seat back
- (23) Fifth seat back
- (24) Seat cushion
- (25) Back panel or door surface
- (26) Other interior component (specify): ______________________

Exterior Components
- (30) Hood
- (31) Outside surface of vehicle (specify): ______________________
- (32) Other exterior object in the environment (specify): ______________________
- (33) Unknown exterior object

(98) Intrusion of unlisted component(s) (specify): ______________________

(99) Unknown

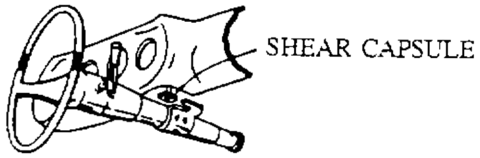
MAGNITUDE OF INTRUSION
- (1) ≥ 1 inch but < 3 inches
- (2) ≥ 3 inches but < 6 inches
- (3) ≥ 6 inches but < 12 inches
- (4) ≥ 12 inches but < 18 inches
- (5) ≥ 18 inches but < 24 inches
- (6) ≥ 24 inches
- (9) Unknown

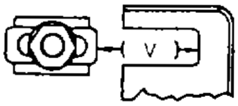
DOMINANT CRUSH DIRECTION
- (1) Vertical
- (2) Longitudinal
- (3) Lateral
- (9) Unknown

STEERING COLUMN WORKING DIAGRAMS

STEERING COLUMN COLLAPSE

Steering Column Shear Module Movement

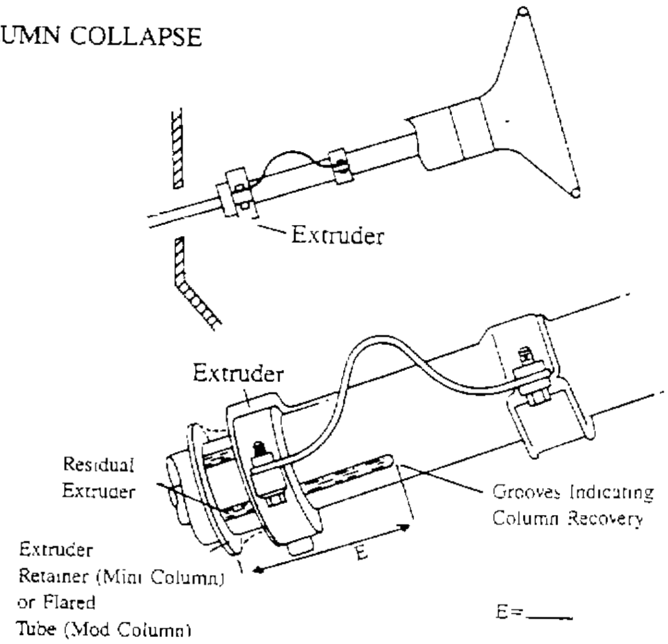




Left ___

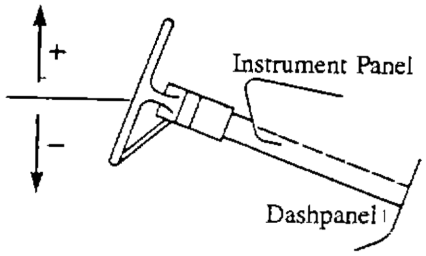
Right ___ V = _______"

Direction and Magnitude of Steering Column Movement

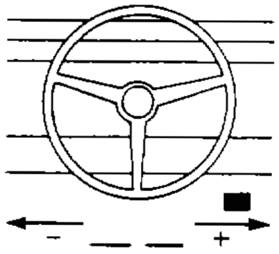


STEERING COLUMN MOVEMENT

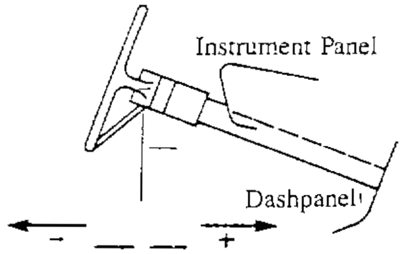
Vertical Movement



Lateral Movement



Longitudinal Movement



	COMPARISON VALUE	–	DAMAGED VALUE	=	MOVEMENT
VERTICAL		–		=	
LATERAL		–		=	
LONGITUDINAL		–		=	

STEERING RIM/SPOKE DEFORMATION

COMPARISON VALUE	–	DAMAGED VALUE	=	DEFORMATION
	–		=	
	–		=	

STEERING COLUMN

87. Steering Column Type ____

(1) Fixed column
(2) Tilt column
(3) Telescoping column
(4) Tilt and telescoping column
(8) Other column type (specify):

____

(9) Unknown

88. Steering Column Collapse Due to Occupant Loading ____

____ Code actual measured movement to the nearest inch. See coding manual for measurement technique(s).

(00) No movement, compression, or collapse
(01-49) Actual measured value
(50) 50 inches or greater

Estimated movement from observation
(81) Less than 1 inch
(82) ≥ 1 inch but < 2 inches
(83) ≥ 2 inches but < 4 inches
(84) ≥ 4 inches but < 6 inches
(85) ≥ 6 inches but < 8 inches
(86) Greater than or equal to 8 inches

(97) Apparent movement, value undetermined or cannot be measured or estimated
(98) Nonspecified type column
(99) Unknown

Direction And Magnitude of Steering Column Movement

89. Vertical Movement ____

90. Lateral Movement ____

91. Longitudinal Movement ____

Code the actual measured movement to the nearest inch. See Coding Manual for measurement technique(s)
(+00) No Steering column movement
(±01 – ±49) Actual measured value
(±50) 50 inches or greater

Estimated movement from observation
(±81) ≥ 1 inch but < 3 inches
(±82) ≥ 3 inches but < 6 inches
(±83) ≥ 6 inches but < 12 inches
(±84) ≥ 12 inches

(__97) Apparent movement > 1 inch but cannot be measured or estimated
(__99) Unknown

92. Steering Rim/Spoke Deformation ____

____ Code actual measured deformation to the nearest inch.

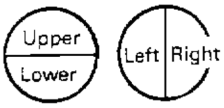
(0) No steering rim deformation
(1-5) Actual measured value
(6) 6 inches or more
(8) Observed deformation cannot be measured
(9) Unknown

93. Location of Steering Rim/Spoke Deformation ____

(00) No steering rim deformation

Quarter Sections
(01) Section A
(02) Section B
(03) Section C
(04) Section D

Half Sections
(05) Upper half of rim/spoke
(06) Lower half of rim/spoke
(07) Left half of rim/spoke
(08) Right half of rim/spoke



(09) Complete steering wheel collapse
(10) Undetermined location
(99) Unknown

INSTRUMENT PANEL

94. Odometer Reading ____,000

____ miles—Code mileage to the nearest 1,000 miles

(000) No odometer
(001) Less than 1,500 miles
(300) 299,500 miles or more
(999) Unknown

Source: ____

95. Instrument Panel Damage from Occupant Contact ____

(0) No
(1) Yes
(9) Unknown

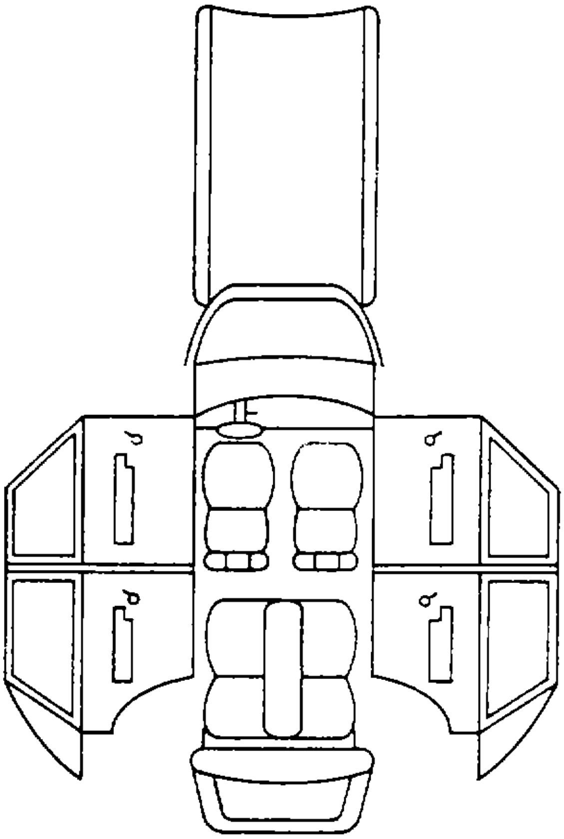
96. Knee Bolsters Deformed from Occupant Contact ____

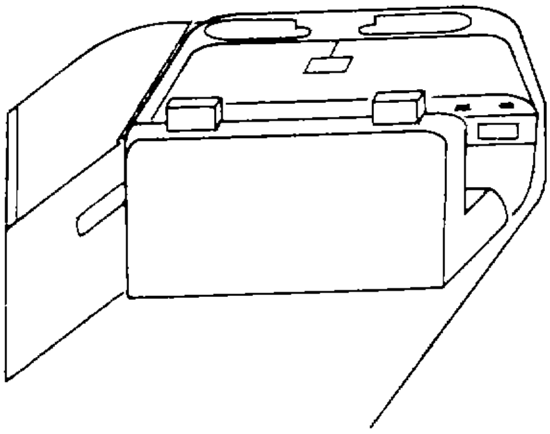
(0) No
(1) Yes
(8) Not present
(9) Unknown

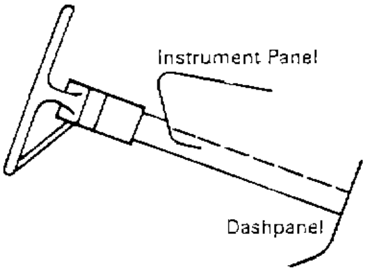
97. Did Glove Compartment Door Open During Collision(s) ____

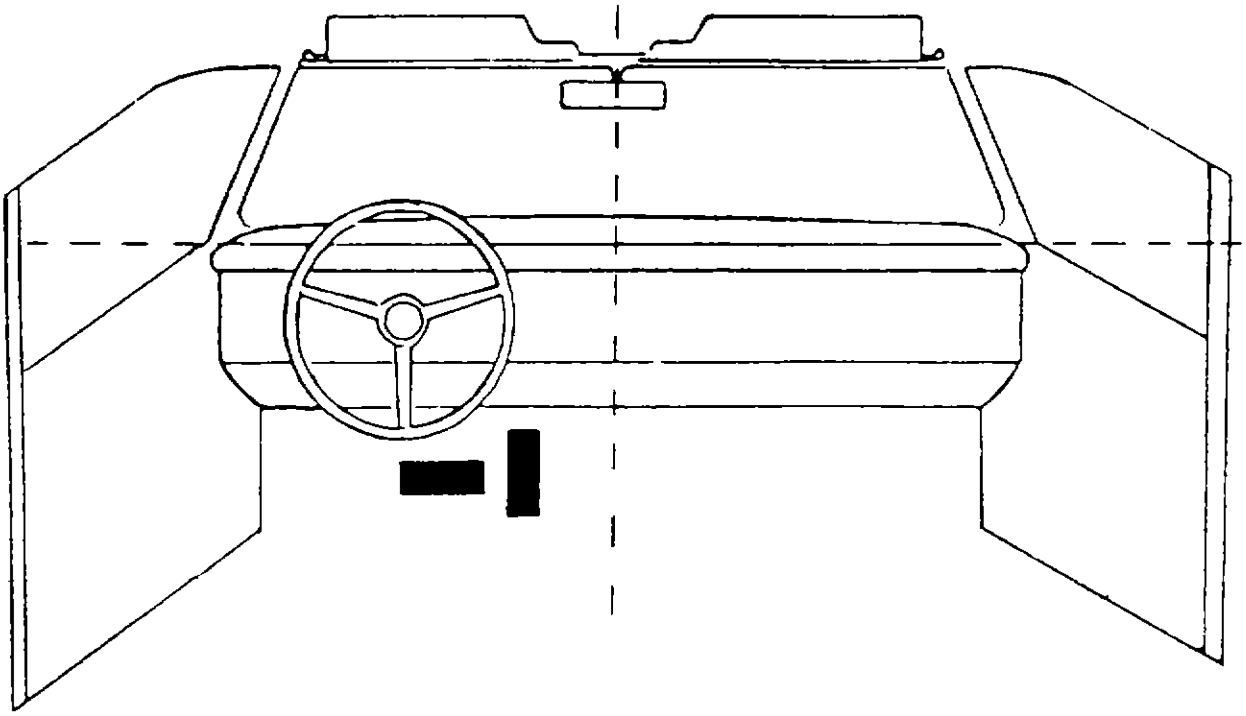
(0) No
(1) Yes
(8) Not present
(9) Unknown

VEHICLE INTERIOR SKETCHES









POINTS OF OCCUPANT CONTACT

Contact	Interior Component Contacted	Occupant No. If Known	Body Region If Known	Supporting Physical Evidence	Confidence Level of Contact Point
A					
B					
C					
D					
E					
F					
G					
H					
I					
J					
K					
L					
M					
N					

CODES FOR INTERIOR COMPONENTS

FRONT
- (01) Windshield
- (02) Mirror
- (03) Sunvisor
- (04) Steering wheel rim
- (05) Steering wheel hub/spoke
- (06) Steering wheel (combination of codes 04 and 05)
- (07) Steering column, transmission selector lever, other attachment
- (08) Add on equipment (e.g., CB, tape deck, air conditioner)
- (09) Left instrument panel and below
- (10) Center instrument panel and below
- (11) Right instrument panel and below
- (12) Glove compartment door
- (13) Knee bolster
- (14) Windshield including one or more of the following: front header, A-pillar, instrument panel, mirror,or steering assembly (driver side only)
- (15) Windshield including one or more of the following: front header, A-pillar, instrument panel, or mirror (passenger side only)
- (16) Other front object (specify): ____________________

LEFT SIDE
- (20) Left side interior surface, excluding hardware or armrests
- (21) Left side hardware or armrest
- (22) Left A pillar
- (23) Left B pillar
- (24) Other left pillar (specify): ____________________
- (25) Left side window glass or frame
- (26) Left side window glass including one or more of the following: frame, window sill, A-pillar, B-pillar, or roof side rail
- (27) Other left side object (specify): ____________________

RIGHT SIDE
- (30) Right side interior surface, excluding hardware or armrests
- (31) Right side hardware or armrest
- (32) Right A pillar
- (33) Right B pillar
- (34) Other right pillar (specify): ____________________
- (35) Right side window glass or frame
- (36) Right side window glass including one or more of the following: frame, window sill, A-pillar, B-pillar, or roof side rail
- (37) Other right side object (specify): ____________________

INTERIOR
- (40) Seat, back support
- (41) Belt restraint webbing/buckle
- (42) Belt restraint B-pillar attachment point
- (43) Other restraint system component (specify): ____________________
- (44) Head restraint system
- (45) Air cushion
- (46) Other occupants (specify): ____________________
- (47) Interior loose objects
- (48) Child safety seat (specify): ____________________
- (49) Other interior object (specify): ____________________

ROOF
- (50) Front header
- (51) Rear header
- (52) Roof left side rail
- (53) Roof right side rail
- (54) Roof or convertible top

FLOOR
- (56) Floor including toe pan
- (57) Floor or console mounted transmission lever, including console
- (58) Parking brake handle
- (59) Foot controls including parking brake

REAR
- (60) Backlight (rear window)
- (61) Backlight storage rack, door, etc.
- (62) Other rear object (specify): ____________________

CONFIDENCE LEVEL OF CONTACT POINT
- (1) Certain
- (2) Probable
- (3) Possible
- (4) Unknown

AUTOMATIC RESTRAINTS

NOTES: Encode the data for each applicable front seat position. The attributes for the variables may be found below. Restraint systems should be assessed during the vehicle inspection then coded on the Occupant Assessment Form.

		Left	Center	Right
FIRST	Availability			
	Function			
	Failure			

Automatic (Passive) Restraint System Availability

(0) Not equipped/not available
(1) Airbag
(2) Airbag disconnected (specify): ______________________
(3) Airbag not reinstalled
(4) 2 point automatic belts
(5) 3 point automatic belts
(6) Automatic belts destroyed or rendered inoperative
(9) Unknown

Automatic (Passive) Restraint Function

(0) Not equipped/not available

Automatic Belt
(1) Automatic belt in use
(2) Automatic belt not in use
(3) Automatic belt use unknown

Air Bag
(4) Airbag deployed during accident
(5) Airbag deployed inadvertently just prior to accident
(6) Deployed, accident sequence undetermined
(7) Nondeployed
(8) Unknown if deployed
(9) Unknown

Did Automatic (Passive) Restraint Fail

(0) Not equipped/not available
(1) No
(2) Yes (specify): ______________________
(9) Unknown

MANUAL RESTRAINTS

NOTES: Encode the applicable data **for each seat position** in the vehicle. The attributes for the variables may be found below. Restraint systems should be assessed during the vehicle inspection then coded on the Occupant Assessment Form.

If a child safety seat is present, encode the data on the back of this page.

If the vehicle has automatic restraints available, encode the appropriate data on the back of the previous page.

		Left	Center	Right
FIRST	Availability			
	Use			
	Failure Modes			
SECOND	Availability			
	Use			
	Failure Modes			
THIRD	Availability			
	Use			
	Failure Modes			
OTHER	Availability			
	Use			
	Failure Modes			

Manual (Active) Belt System Availability

(0) Not available
(1) Belt removed/destroyed
(2) Shoulder belt
(3) Lap belt
(4) Lap and shoulder belt
(5) Belt available – type unknown
(8) Other belt (specify):

(9) Unknown

Manual (Active) Belt System Use

(00) None used, not available, or belt removed/destroyed
(01) Inoperative (specify):

(02) Shoulder belt
(03) Lap belt
(04) Lap and shoulder belt
(05) Belt used – type unknown

(08) Other belt used (specify):

(12) Shoulder belt used with child safety seat
(13) Lap belt used with child safety seat
(14) Lap and shoulder belt used with child safety seat
(15) Belt used with child safety seat – type unknown
(18) Other belt used with child safety seat (specify):

(99) Unknown if belt used

Manual (Active) Belt Failure Modes During Accident

(0) No manual belt used or not available
(1) No manual belt failure(s)
(2) Manual belt failure(s) (encode all that apply above)
[A] Torn webbing (stretched webbing not included)
[B] Broken buckle or latchplate
[C] Upper anchorage separated
[D] Other achorage separated (specify):

[E] Broken retractor
[F] Other manual belt failure (specify):

(9) Unknown

CHILD SAFETY SEAT FIELD ASSESSMENT

When a child safety seat is present enter the occupant's number in the first row and complete the column below the occupant's number using the codes listed below. Complete a column for each child safety seat present.

Occupant Number						
1. Type of Child Safety Seat						
2. Child Safety Seat Orientation						
3. Child Safety Seat Harness Usage						
4. Child Safety Seat Shield Usage						
5. Child Safety Seat Tether Usage						
6. Child Safety Seat Make/Model	Specify Below for Each Child Safety Seat					

1. Type of Child Safety Seat

(0) No child safety seat
(1) Infant seat
(2) Toddler seat
(3) Convertible seat
(4) Booster seat
(7) Other type child safety seat (specify):

____

(8) Unknown child safety seat type
(9) Unknown if child safety seat used

2. Child Safety Seat Orientation

(00) No child safety seat

Designed for Rear Facing for This Age/Weight
(01) Rear facing
(02) Forward facing
(03) Other orientation (specify):

____

(04) Unknown orientation

Designed for Forward Facing for This Age/Weight
(11) Rear facing
(12) Forward facing
(18) Other orientation (specify):

____

(19) Unknown orientation

Unknown Design or Orientation for This Age/Weight, or Unknown Age/Weight
(21) Rear facing
(22) Forward facing
(28) Other orientation (specify):

____

(29) Unknown orientation

(99) Unknown if child safety seat used

3. Child Safety Seat Harness Usage

4. Child Safety Seat Shield Usage

5. Child Safety Seat Tether Usage

Note: Options Below Are Used for Variables 3-5.

(00) No child safety seat

Not Designed with Harness/Shield/Tether
(01) After market harness/shield/tether added, not used
(02) After market harness/shield/tether used
(03) Child safety seat used, but no after market harness/shield/tether added
(09) Unknown if harness/shield/tether added or used

Designed with Harness/Shield/Tether
(11) Harness/shield/tether not used
(12) Harness/shield/tether used
(19) Unknown if harness/shield/tether used

Unknown if Designed with Harness/Shield/Tether
(21) Harness/shield/tether not used
(22) Harness/shield/tether used
(29) Unknown if harness/shield/tether used

(99) Unknown if child safety seat used

6. Child Safety Seat Make/Model
(Specify make/model and occupant number)

____

____

____

____

HEAD RESTRAINTS/SEAT EVALUATION

NOTES: Encode the applicable data for **each seat position** in the vehicle. The attributes for these variables may be found at the bottom of the page. Head restraint type/damage and seat type/performance should be assessed during the vehicle inspection then coded on the Occupant Assessment Form.

		Left	Center	Right
FIRST	Head Restraint Type/Damage			
	Seat Type			
	Seat Performance			
SECOND	Head Restraint Type/Damage			
	Seat Type			
	Seat Performance			
THIRD	Head Restraint Type/Damage			
	Seat Type			
	Seat Performance			
OTHER	Head Restraint Type/Damage			
	Seat Type			
	Seat Performance			

Head Restraint Type/Damage by Occupant at This Occupant Position

(0) No head restraints
(1) Integral – no damage
(2) Integral – damaged during accident
(3) Adjustable – no damage
(4) Adjustable – damaged during accident
(5) Add-on – no damage
(6) Add-on – damaged during accident
(8) Other (specify): ____________________
(9) Unknown

Seat Type (This Occupant Position)

(00) Occupant not seated or no seat
(01) Bucket
(02) Bucket with folding back
(03) Bench
(04) Bench with separate back cushions
(05) Bench with folding back(s)
(06) Split bench with separate back cushions
(07) Split bench with folding back(s)
(08) Pedestal (i.e., van type)
(09) Other seat type (specify): ____________________
(99) Unknown

Seat Performance (This Occupant Position)

(0) Occupant not seated or no seat
(1) No seat performance failure(s)

(2) Seat performance failure(s)
(Encode all that apply)

[A] Seat adjusters failed
[B] Seat back folding locks failed
[C] Seat tracks failed
[D] Seat anchors failed
[E] Deformed by impact of passenger from rear
[F] Deformed by impact of passenger from front
[G] Deformed by own inertial forces
[H] Deformed by passenger compartment intrusion (specify):
____
____
____
[I] Other (specify): ____________________
____

(9) Unknown

DESCRIBE ANY INDICATION OF ABNORMAL OCCUPANT POSTURE (I.E. UNUSUAL OCCUPANT CONTACT PATTERN)

EJECTION/ENTRAPMENT DATA

Complete the following if the researcher has any indications that an occupant was either ejected from or entrapped in the vehicle. Code the appropriate data on the Occupant Assessment Form.

EJECTION No [ ] Yes [ ]

Describe indications of ejection and body parts involved in partial ejection(s):

____

____

____

____

____

Occupant Number						
Ejection						
Ejection Area						
Ejection Medium						
Medium Status						

Ejection
- (1) Complete ejection
- (2) Partial ejection
- (3) Ejection, unknown degree
- (9) Unknown

Ejection Area
- (1) Windshield
- (2) Left front
- (3) Right front
- (4) Left rear
- (5) Right rear
- (6) Rear
- (7) Roof
- (8) Other area (e.g., back of pickup, etc.) (specify): ______________
- (9) Unknown

Ejection Medium
- (1) Door/hatch/tailgate
- (2) Nonfixed roof structure
- (3) Fixed glazing
- (4) Nonfixed glazing (specify): ______________
- (5) Integral structure
- (8) Other medium (specify): ______________
- (9) Unknown

Medium Status (Immediately Prior to Impact)
- (1) Open
- (2) Closed
- (3) Integral structure
- (9) Unknown

ENTRAPMENT No [ ] Yes [ ]

Describe entrapment mechanism: ______________________________

____

____

____

____

Component(s): ______________________________

____

(Note in vehicle interior diagram)

U.S. Department of Transportation
National Highway Traffic Safety Administration

NATIONAL ACCIDENT SAMPLING SYSTE
CRASHWORTHINESS DATA SYSTE

CRASHPC PROGRAM SUMMARY

Identifying Title

___ ___	___ ___ ___ – ___	___ ___	___ ___ ___ ___ ___ ___
Primary Sampling Unit	Case No. – Stratum	Accident Event Sequence No.	Date (mm dd yy)

CRASHPC Vehicle Identification

	Year	Make	Model	NASS Veh. No.
Vehicle 1	______	______	______	______
Vehicle 2	______	______	______	______

GENERAL INFORMATION

VEHICLE 1		VEHICLE 2	
Size	___	Size	___
Weight ______ (Curb) + ______ (Occupant(s)) + ______ (Cargo) =	___ ___ ___ ___	Weight ______ (Curb) + ______ (Occupant(s)) + ______ (Cargo) =	___ ___ ___ ___
CDC	___ ___ ___ ___ ___ ___ ___	CDC	___ ___ ___ ___ ___ ___ ___
PDOF	___ ___ ___	PDOF	___ ___ ___
Stiffness	___	Stiffness	___

SCENE INFORMATION

Rest and Impact Positions [ ] No, ***Go To Damage Information*** [ ] Yes

VEHICLE 1		VEHICLE 2	
Rest Position		Rest Position	
X	___ ___ ___ . ___	X	___ ___ ___ . ___
Y	___ ___ ___ . ___	Y	___ ___ ___ . ___
PSI	___ ___ ___ . ___	PSI	___ ___ ___ . ___
Impact Position		Impact Position	
X	___ ___ ___ . ___	X	___ ___ ___ . ___
Y	___ ___ ___ . ___	Y	___ ___ ___ . ___
PSI	___ ___ ___ . ___	PSI	___ ___ ___ . ___
Slip Angle	___ ___ ___	Slip Angle	___ ___ ___

VEHICLE MOTION

Sustained Contact [ ] No [ ] Yes

VEHICLE 1			VEHICLE 2		
Skidding	[ ] No	[ ] Yes	**Skidding**	[ ] No	[ ] Yes
Skidding Stop Before Rest	[ ] No	[ ] Yes	Skidding Stop Before Rest	[ ] No	[ ] Yes
End-of-Skidding Position			End-of-Skidding Position		
X	___ ___ ___ . ___		X	___ ___ ___ . ___	
Y	___ ___ ___ . ___		Y	___ ___ ___ . ___	
PSI	___ ___ ___ . ___		PSI	___ ___ ___ . ___	
Curved Path	[ ] No	[ ] Yes	**Curved Path**	[ ] No	[ ] Yes
Point on Path			Point on Path		
X ___ ___ ___ . ___	Y ___ ___ ___ . ___		X ___ ___ ___ . ___	Y ___ ___ ___ . ___	
Rotation Direction [ ] None	[ ] CW	[ ] CCW	**Rotation Direction** [ ] None	[ ] CW	[ ] CCW
Rotation > 360°	[ ] No	[ ] Yes	Rotation > 360°	[ ] No	[ ] Yes

HS Form 435D
1/88

FRICTION INFORMATION

Coefficient of Friction . ___ ___ ___

Rolling Resistance Option ___

Vehicle 1 Rolling Resistance

LF ___ . ___ ___ RF ___ . ___ ___

LR ___ . ___ ___ RR ___ . ___ ___

Vehicle 2 Rolling Resistance

LF ___ . ___ ___ RF ___ . ___ ___

LR ___ . ___ ___ RR ___ . ___ ___

TRAJECTORY INFORMATION

Trajectory Data [ ] No [ ] Yes

If No, Go To Damage Information

Vehicle 1 Steer Angles

LF ___ ___ ___ RF ___ ___ ___

LR ___ ___ ___ RR ___ ___ ___

Vehicle 2 Steer Angles

LF ___ ___ ___ RF ___ ___ ___

LR ___ ___ ___ RR ___ ___ ___

Terrain Boundary [ ] No [ ] Yes

First Point

X ___ ___ ___ . ___ Y ___ ___ ___ . ___

Second Point

X ___ ___ ___ . ___ Y ___ ___ ___ . ___

Secondary Friction Coefficient . ___ ___ ___

DAMAGE INFORMATION

	VEHICLE 1		VEHICLE 2
Damage Length	___ ___ ___ . ___ ___	Damage Length	___ ___ ___ . ___ ___
Crush Depths	C1 ___ ___ . ___ ___	Crush Depths	C1 ___ ___ . ___ ___
	C2 ___ ___ . ___ ___		C2 ___ ___ . ___ ___
	C3 ___ ___ . ___ ___		C3 ___ ___ . ___ ___
	C4 ___ ___ . ___ ___		C4 ___ ___ . ___ ___
	C5 ___ ___ . ___ ___		C5 ___ ___ . ___ ___
	C6 ___ ___ . ___ ___		C6 ___ ___ . ___ ___
Damage Offset	± ___ ___ ___ . ___ ___	Damage Offset	± ___ ___ ___ . ___ ___

IF THIS COMMON IMPACT WAS WITH A MOTOR VEHICLE *NOT IN TRANSPORT*, FILL IN THE INFORMATION BELOW.

Model Year: ______________________

Make: ______________________

Model: ______________________

VIN: ______________________

The Weight, CDC, Scene Data and Damage Information for this vehicle should be recorded above.

Complete and ATTACH the appropriate vehicle damage sketch and dimensions to the Form.

9. Basis for Total Delta V (Highest) ___

Delta V Calculated
(1) CRASH program—damage only routine
(2) CRASH program—damage and trajectory routine
(3) Missing vehicle algorithm

Delta V Not Calculated
(4) At least one vehicle (which may be this vehicle) is beyond the scope of an acceptable reconstruction program, regardless of collision conditions.

(5) All vehicles within scope (CDC applicable) of CRASH program but one of the collision conditions is beyond the scope of the CRASH program or other acceptable reconstruction techniques, regardless of adequacy of damage data.

(6) All vehicle and collision conditions are within scope of one of the acceptable reconstruction programs, but there is insufficient data available.

COMPUTER GENERATED DELTA V

Secondary Highest

0. Total Delta V ___ ___

___ **Nearest mph** ___

(NOTE: 00 means less than 0.5 mph)
(97) 96.5 mph and above
(99) Unknown

31. Longitudinal Component of Delta V + ___ ___ ___

___ **Nearest mph** ___

(NOTE: __00 means greater than −0.5 and less than +0.5 mph)
(±97) ±96.5 mph and above
(__ 99) Unknown

Secondary Highest

32. Lateral Component of Delta V + ___ ___ ___

___ Nearest mph ___

(NOTE: __00 means greater than −0.5 and less than +0.5 mph)
(±97) ±96.5 mph and above
(__ 99) Unknown

33. Energy Absorption ___ ___ ___, ___ 0 0

___ Nearest 100 foot-lbs ___

(NOTE: 0000 means less than 50 Foot-Lbs)
(9997) 999,650 foot-lbs or more
(9999) Unknown

34. Confidence in Reconstruction Program Results (for Highest Delta V) ___
(0) No reconstruction
(1) Collision fits model—results appear reasonable
(2) Collision fits model—results appear high
(3) Collision fits model—results appear low
(4) Borderline reconstruction—results appear reasonable

35. Type of Vehicle Inspection ___
(0) No Inspection
(1) Complete inspection
(2) Partial inspection (specify):

___

***** STOP HERE IF THE CDS APPLICABLE *****
VEHICLE WAS NOT INSPECTED