5. CRASHED VEHICLE STUDY

Detailed and reliable information on impact direction, vehicle damage and personal injury to establish causal relationships in occupant injuries is not possible from analysis of mass data. Retrospective data collection and analysis can only provide **correlational** associations between vehicles, crash types and subsequent injuries and very few details on the type or extent of vehicle damage involved.

Hence, it was necessary to undertake a prospective study of a sample of crashed vehicles to provide **causal** information on the sources of injury to vehicle occupants in typical on-road crashes. This was to provide details on improvements required in vehicle design and construction to reduce the frequency and/or severity of these injuries. To facilitate these improvements and help determine priorities, 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.

5.1 METHOD

A method was developed for the detailed assessment of the extent of occupant injuries and the vehicle damage for a sample of passenger car crashes that occurred in urban and rural Victoria after the 1st April 1989. As the study was primarily concerned with secondary safety aspects of the vehicle's performance rather than crash causal information, in-depth analysis at-the-scene was not attempted.

The alternative approach involving immediate follow-up of the crash victims within one or two days and location and inspection of the crashed vehicle at the tow yard, vehicle repairer, or wreckers lot was adopted here. This method has been successfully used by a number of international organisations concerned with secondary safety (eg, Birmingham and Loughborough Accident Research Units in the U.K. and BMW in Germany).

5.1.1 The Crashed Vehicle Population

The population of crashed vehicles comprised post-1981 passenger cars and their derivatives (station wagons, panel vans, etc) that were involved in a road crash where at least one occupant was injured severely enough to require admission to hospital. Fatal crashes, where no occupant survived sufficiently long enough to be admitted to hospital, were excluded because of the severity of the collision and the greater difficulty in determining design improvements. However, collisions involving a fatality to another occupant or where the patient died after admission to hospital were included.

5.1.2 Procedure

The process was triggered by the admission of a suitable road crash victim at one of four Melbourne hospitals which had agreed to participate in the study. Patients were screened by a research assistant (nurse) at each hospital for the type of crash and suitability of the vehicle. These patients were then asked whether they were willing to participate in the study and signed an agreement form. Crash and patient injury details were obtained from the patient's medical record and from details obtained from the patient during an interview. In addition, permission was also sought to inspect the vehicle involved in the crash.

The crashed vehicle was subsequently located and an inspection crew was dispatched to make the necessary measurements and photographs of the extent of damage (see Attachment 1 for a full description of the inspection process). Where a second vehicle was involved, it was also tracked down and briefly examined to complete the details required to explain the damage and to calculate the impact velocity. Each case was fully documented and coded into a computer database for subsequent analysis.

5.1.3 Calculation of Impact Velocity

Impact speed in this study was defined as the change in velocity from the moment of impact until the study vehicle separated from its impacting source (delta-V). As noted earlier, this was calculated in this research 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 which are subject to some error from its assumptions and the vehicle stiffness values used in these calculations. In this study, the American vehicle stiffness values were used in the calculations of delta-V for vehicles of the same sizes as the Australian vehicles. These errors may be reduced if the appropriate stiffness values for each vehicle in this study were to be supplied by the local manufacturers.

5.1.4 Selection Criteria

The inclusion/exclusion criteria used in the study for determining the suitability of a crash are described below. Using these inclusion/exclusion criteria, roughly, one in twenty-five road trauma attendances were suitable for inclusion in the study.

VEHICLE SUITABILITY - Any car or derivative with a Victorian registration number that commenced with either a "B, C or D" or a personalised plate (this effectively included all vehicles first registered during 1982 or later). Any vehicle subsequently found to be re-registered or unsuitable was excluded from the study by the project team at a later date. Four-wheel drive vehicles of a standard car design (eg, Subaru models or Toyota Tercel) were included as suitable vehicles. However, the usual high clearance four-wheel drive vehicle configuration was not considered to be a passenger car derivative and they were excluded from this study.

CRASH SUITABILITY - Because of the difficulty in interpreting the effects of multiple collisions and which crash caused which injury, only single collisions were included. The impacted object could have been either another car, a truck, or a movable or immovable object, including rollovers. Where there was clear evidence that a vehicle occupant had been fully ejected from a vehicle during the collision (such as thrown from a vehicle during a rollover), they were excluded from the study. This was because of the impossibility of interpreting vehicle injury source information for these cases. However, where a belted occupant suffered damage as a result of either a full or partial ejection from the vehicle, an assessment of vehicle contribution to their injuries was attempted.

PATIENT SUITABILITY - Patient suitability consisted of any vehicle occupant who was admitted to one of the participating hospitals from a suitable vehicle or collision. The patient had to be defined as a recent road accident victim (TAC, MCA or other hospital coding) rather than a re-admission from a previous crash. Patients could be conscious or unconscious and fatalities and patients that subsequently died in hospital were also included to ensure a broad range of injuries and different crash severities.

In most cases it was not possible to obtain details on all occupants involved in the collision. However, where the condition and circumstances of other injured occupants could be obtained, these details were also collected. This included both adults and children. While occupants are required by law to be belted in all vehicles, a number of them nevertheless do not wear seat belts in cars. Hence, it was felt legitimate 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.

5.1.5 Hospital Participation

Approval to approach and interview patients was obtained from the ethics committees of **four** major road trauma hospitals in the Melbourne Metropolitan area, namely the Alfred, Box Hill, Dandenong & District, and Monash Medical Centre (the latter hospital was a late inclusion in the study and, to date, has not yielded very many patients because of its recent entry into road trauma admissions). Approval was subject to obtaining patient approval as well as ensuring confidentiality of this information.

For each week of the study, an average of 100 patients were admitted at the four study hospitals requiring treatment from road crashes. After applying selection criteria, approximately four patients weekly were judged suitable for inclusion in the study (non-acceptable patients included pedestrians, motorcyclists, bicyclists, and non-eligible vehicles). Refusal rates in the study were extremely low (7 out of every 100 patients expressed a desire not to participate).

5.1.6 Patient & Vehicle Assessment

The assessment and classification of injuries sustained by road trauma patients (including injury severity judgements) requires specialised medical training and skills. Two former nurses were employed by MUARC as research assistants to undertake these duties and were extensively trained in the collection of injury data for research purposes and in making Abbreviated Injury Score (AIS) assessments of injury severity (Ozanne-Smith 1988). A hospital proforma was developed to provide a standardised format for the collection of the patient's medical, vehicle, and crash information which was trialled and modified prior to commencement of its use in the project (see Attachment 2).

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 several other centres in Australia and overseas. Information and discussion of inspection procedures was undertaken by the authors during overseas visits (Fildes and Vulcan 1989) and when overseas and local experts visited MUARC (eg, Professor Murray Mackay, Dr. Bob Campbell, Professor Kennerly Digges, and Mr. Tom Gibson). The team is grateful for their advice.

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 5.1 shows the NASS vehicle proforma for coding impact direction and vehicle region.

A mechanical engineer was employed to undertake this task and given the necessary training in undertaking these inspections (details on the inspection procedure used are described in Attachment 1). When these site data were complete, Delta-V impact velocity calculations were undertaken and the injury and vehicle damage information was coded into a computer database for subsequent analysis. The reliability of the engineer's judgements at assessing injury and vehicle component interactions was compared with judgements made by the project's consultant epidemiologist, Dr. J.C. Lane, and Mr. Tom Gibson of the N.S.W. Road and Traffic Authority. The inter-rater reliability assessment was 70% for these judges.

5.2 VARIABLES & DATA ANALYSIS

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 use of restraint assessment was especially relevant in this study as the inspection method used has been shown to be the only objective and accurate means of making these assessments, Cromark, Schneider and Blaisdell 1990).

The dependent variables comprised crash and injury involvement rates per 100 vehicles or patients relative to the population of crashes investigated in the follow-up study of crashed vehicles. Interactions between injury and vehicle source were especially important comparisons 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.

5.3 OVERALL RESULTS

At the time of publication of this report, there were details available for analysis on 227 vehicles involving 269 patients from crashes that occurred in Victoria between the 1st April 1989 and the 31st August 1990, comprising 69% metropolitan and 31% rural crashes. The crashed vehicle database comprises information on 572 variables for each crash investigated. The results are described in terms of the variables of interest.

5.3.1 Crash & Vehicle Characteristics

There were slight differences in the sample of crash vehicles to that observed for all hospitalised patients in the mass data analysis. Details of the comparative crash, vehicle, and patient characteristics of this sample with the mass data equivalents are shown in Table 5.1 and are described below.

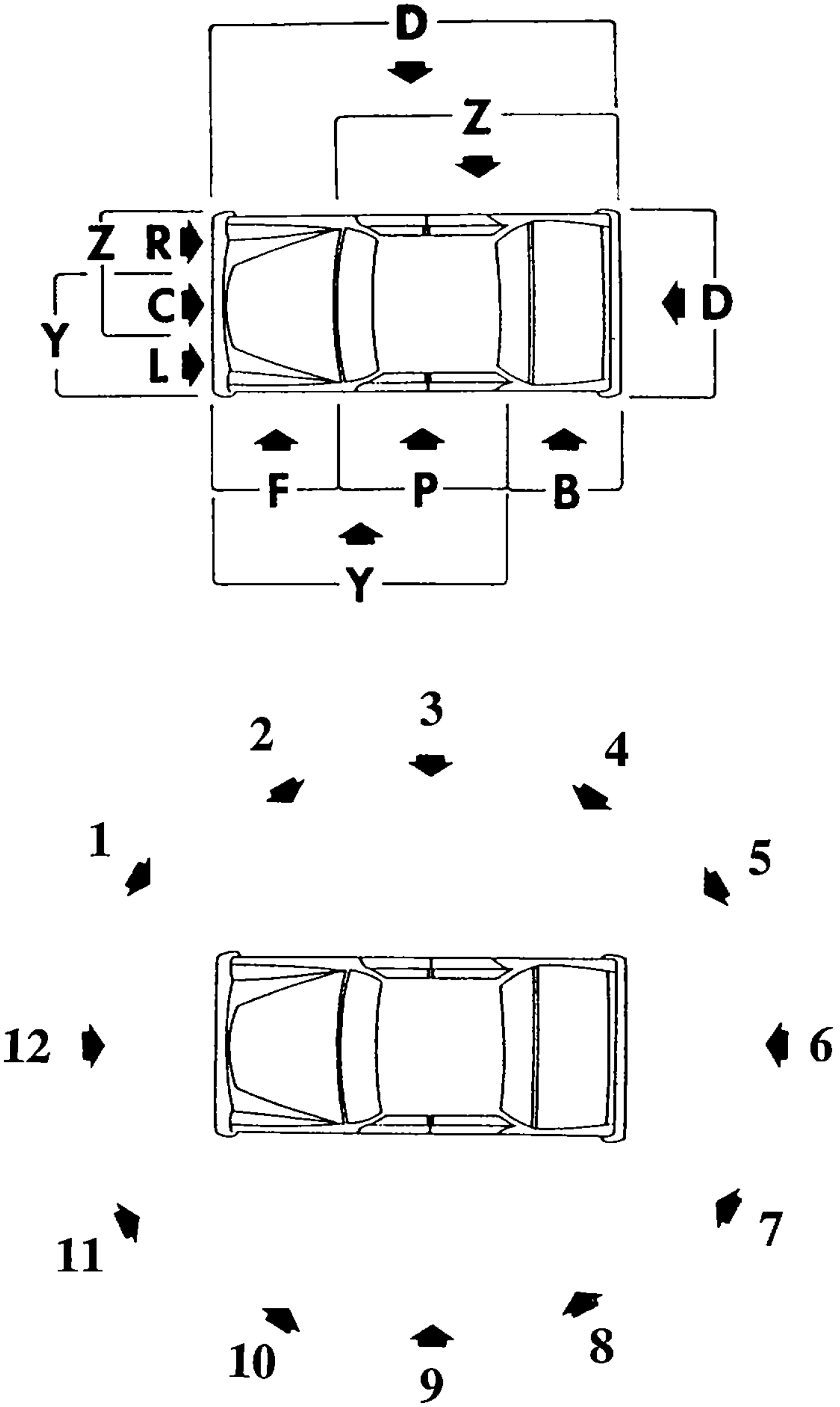
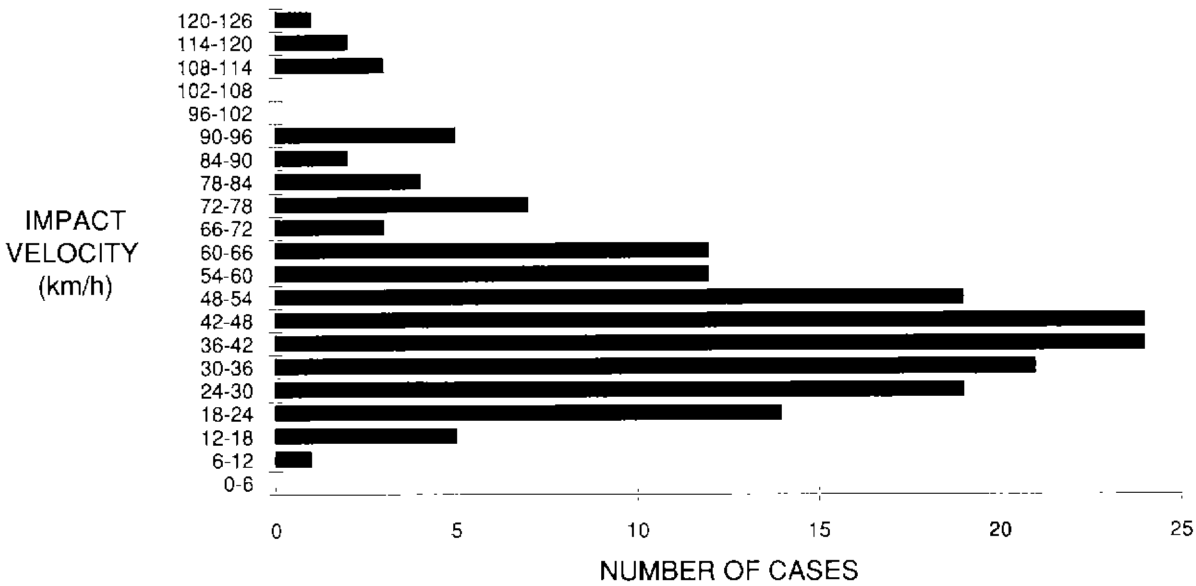


Figure 5.1 *National Accident Sampling System proforma for coding vehicle impact location and direction.*

CRASH TYPE - Frontal crashes accounted for 60% of crashed vehicles inspected, side impact 35%, rollovers 5%, and there were no rear-end collisions included in the sample. While the proportion of frontal collisions was roughly equal in both data sets, there were differences in the proportions of side impact (35% cf. 14%), rear end (0% cf. 11%), and rollovers (5% cf. 10%). The more accurate means of assessment of impact direction here (and possibly the selection criteria too) appear to have had some influence on crash type in these data.

IMPACT VELOCITY - The mean estimated delta-V value in Table 5.1 was 45.4km/h with a standard deviation of 23.3km/h. Furthermore, Figure 5.2 shows a modal value between 36 and 42km/h and a range from 3 to over 111km/h. Seventy percent of all delta-V values were equal to or below 48km/h (30mph). Impact speed was not available in the mass data base.

Figure 5.2 Frequency histogram of impact velocities (delta-V) observed for the total sample of vehicles inspected to date.



VEHICLE TYPE - Table 5.1 shows that 5% of the crashed vehicles were mini-cars (<750kg), 25% were small (<1000kg), 40% compacts (1001-1250kg), 28% intermediates (1251-1500kg), and 2% large cars (>1500kg). There were differences in the proportions of vehicle sizes observed in this sample compared with the mass data. In particular, small cars were under-represented (25% cf. 41%) while intermediate and large cars were over-represented (30% cf. 19%), accounting for the marginal difference in mean vehicle weight observed between these two data sets (1089kg cf. 1069kg).

Because of small numbers involved in the extreme sizes, the five vehicle categories were subsequently collapsed into small cars (<1000kg), compacts (1001-1250kg), and large cars (>1250kg) for further analysis. Table 5.2 lists the various makes and models of vehicles that were examined in this study. Unfortunately, there are no accurate figures available on the proportions of vehicle models in the current vehicle population in Victoria to gauge relative involvement rates. Thirty six percent of the vehicles had manual transmissions while the rest were automatics. Front-wheel drive transmission was observed in 43% of the crashed vehicles, rear-wheel drive in 54%, and four-wheel drive in 3%.

5.3.2 Patient Characteristics

Table 5.1 further shows that there were slight differences in the population of injured occupants in this sample to that observed in the mass data for occupants admitted to hospital. Sixty two percent of patients were drivers (compared to 58%), 25% were front-left seat occupants (cf. 27%), while 13% were rear seat occupants (cf. 15%).

TABLE 5.1
POPULATION CHARACTERISTICS OF THE CRASHED VEHICLE STUDY WITH EQUIVALENT "HOSPITALISED" MASS DATA VALUES

CHARACTERISTIC	CRASHED VEHICLE	MASS DATA
1. IMPACT VELOCITY		
Mean Delta-V	45.4km/h	-
Standard Deviation	23.3km/h	-
Range	3-111km/h	
2. CRASH TYPE		
Frontal	60%	65%
Side impact	35%	14%
Rear end	0%	11%
Rollover	5%	10%
3. VEHICLE TYPES		
Mini	5%	2%
Small	25%	41%
Compact	40%	38%
Intermediates	28%	16%
Large	2%	3%
Mean vehicle weight	1089kg	1069kg
4. SEATING POSITION		
Driver	62%	58%
Front-Left	25%	27%
Rear	13%	15%
5. PATIENT SEX		
Males	49%	46%
Females	51%	54%
6. PATIENT AGE		
< 17 years	8%	8%
17 - 25 yrs	27%	21%
26 - 55 yrs	47%	47%
56 - 75 yrs	15%	20%
> 75 years	3%	4%

TABLE 5.2
LIST OF THE CRASHED VEHICLE FLEET (n=227)

VEHICLE MAKE/MODEL	FREQUENCY	PERCENTAGE	MASS (RANGE)
Holden Commodore/Calais	40	17.6	1215-1367kg
Ford Falcon/Fairmont	32	14.1	1333-1520kg
Ford Laser/Meteor/Mazda 323	21	9.3	820- 995kg
Nissan Pulsar/Holden Astra	13	5.7	890- 936kg
Toyota Corolla	13	5.7	910- 970kg
Holden Camira	10	4.4	1021-1122kg
Mitsubishi Sigma	9	4.0	1095-1250kg
Mazda 626/Ford Telstar	8	3.5	1003-1155kg
Mitsubishi Magna	8	3.5	1193-1265kg
Nissan Bluebird	8	3.5	1080-1200kg
Holden Barina	6	2.6	710kg
Toyota Corona/Camry	6	2.6	1060-1150kg
Mitsubishi Colt	5	2.2	911- 940kg
Nissan Skyline	5	2.2	1215-1250kg
Nissan Pintara	4	1.8	1150-1287kg
Daihatsu Charade	3	1.3	675- 710kg
Honda Civic	3	1.3	825- 920kg
Mazda 929	3	1.3	1135-1280kg
Toyota Celica	3	1.3	1150-1165kg
Toyota Cressida	3	1.3	1340-1360kg
Hyundai Excel	2	0.9	950kg
Rover Vitesse	2	0.9	1900kg
Suzuki Hatch	2	0.9	680- 730kg
Subaru Leone	2	0.9	945-1005kg
Suzuki Vitara	2	0.9	980-1030kg
Alfa Alfetta	1	0.4	1140kg
Honda Accord	1	0.4	977- 992kg
Honda Integra	1	0.4	1122-1140kg
Honda Prelude	1	0.4	985- 995kg
Mazda RX7	1	0.4	1095kg
Mercedes 450SE	1	0.4	1740-1935kg
Mercedes 230E	1	0.4	1480kg
Mercedes 190D	1	0.4	1210kg
Nissan Gazelle	1	0.4	1100-1120kg
Nissan Stanza	1	0.4	955- 960kg
Porsche 944	1	0.4	1180kg
Saab 900	1	0.4	1185-1315kg
Subaru DL 18	1	0.4	1075-1080kg
Volvo 244	1	0.4	1250-1338kg

Note: *A summary of each of these cases is available in the supplementary volume to this report.*

The sample comprises 49% males and 51% females, which is roughly equivalent to the population ratios in the mass data. Eight percent of the patients were aged under 17 years, 27% were between 17 and 25 years, 47% were 26 to 55 years old, 15% were 56 to 75 years, and 3% were over 75 years. This shows a slight tendency towards younger occupants in this study compared with to the TAC figures. As expected in both data bases, 17 to 25 year olds were well over-represented, compared with both population and license holder proportions in Victoria.

5.3.3 Body Regions & Injuries

The National Accident Sampling System occupant injury classification system 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** injury categories for analysis, namely head, face, chest, abdomen, pelvis, upper extremity, thigh and knee, lower leg, and spine. These categories were based on those commonly reported and discussed in the literature and provided a manageable set of injury categories for detailed analysis.

Table 5.3 shows that drivers recorded the highest average number of body regions injured across all crash types at 4.5 per patient, compared to 3.9 for front-left and rear seat passengers. Drivers and rear passengers recorded slightly more severe injuries (AIS>2) per patient (1.0), in contrast to front-left passengers (0.9).

For all injuries to drivers, the most frequent body regions injured for all collisions were upper extremity (68%), chest (67%), face (67%), head (61%), and knee and thigh (53%). For severe injuries (AIS>2) to drivers, the most frequent body regions injured were the chest (26%), head (18%), and lower leg and foot (16%). There were 61% total injuries and 16% severe injuries to drivers' abdomen and pelvis. For front-left passengers, the most frequent body regions injured were the chest (70%), face (50%), and head (48%), while for severe injuries, the order included the chest (26%), head (12%), pelvis (12%), and upper extremity (11%). Again, there were a sizable number of total injuries (77%) to the abdomen and pelvis of these front seat passengers. For rear seat passengers, the most frequent body regions injured comprised the abdomen (65%), chest (56%), upper extremity (56%), and spine (44%), while for severe injuries only, the most frequent body region injured were the abdomen (26%), chest (26%), head (18%), and upper extremity (12%). There were no severe injuries to the face or lower leg and foot in this rear seating position.

INJURY SEVERITY - Table 5.4 further shows the incidence of injury and the probability of serious injury (Abbreviated Injury Score AIS>2, Injury Severity Score ISS>15, or ISS>25) by seating position in the vehicle. The Injury Severity Score ranking is similar to the ranking by number of injuries for each seating position reported earlier. However, the probabilities of severe injury suggest that drivers are more likely to incur serious injuries than all other occupants, while front-left passengers slightly more at risk of a very severe injury (ISS>25) than drivers. Care needs to be taken with these figures, though, because of the small numbers involved in some of these cells.

5.3.4 Points Of Contact

The NASS injury source classification further allows for scoring 82 specific 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. The vehicle contact regions included 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 other/unknown. Steering column also included pedal contacts, floor included the toe pan in the front, instrument panel comprised both upper and lower sections, while side glazing combined contacts to the glass and the door frame.

Table 5.5 shows that across all occupant injuries and collision types, the most frequent points of contact for drivers were the steering wheel (53%), seat belts (49%), instrument panel (49%), door panel (28%), floor and toe pan (25%), and non-contacts (25%). The contact points for severe injuries (AIS>2) to drivers included the steering wheel (19%), door panel (19%), and instrument panel (12%).

The most frequent points of contact for front-left passengers were the door panel (46%), seat belts (46%), instrument panel (41%), non-contacts (21%), and windscreen and header (20%). The two

TABLE 5.3
BODY REGION INJURED FOR ALL COLLISIONS

BODY REGION INJURED	DRIVERS (n=167) ALL (AIS>2)	FRONT LEFT (n=66) ALL (AIS>2)	REAR (n=34) ALL (AIS>2)
Head	61% (18%)	48% (12%)	35% (18%)
Face	67% (4%)	50% (2%)	44% (0%)
Chest	67% (26%)	70% (26%)	56% (26%)
Abdomen	42% (6%)	44% (9%)	65% (26%)
Pelvis	29% (10%)	33% (12%)	24% (3%)
Upper extremity	68% (10%)	47% (11%)	56% (12%)
Knee & thigh	53% (10%)	30% (8%)	24% (9%)
Lower leg & foot	43% (16%)	38% (5%)	38% (0%)
Spine	25% (4%)	27% (9%)	44% (3%)
Average/Patient	**4.5 (1.0)**	**3.9 (0.9)**	**3.9 (1.0)**

Figures for ALL injuries refers to the percentage of patients 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 per patient show the mean number of total body regions injured and the mean number of serious body regions injured recorded per patient.

TABLE 5.4
SEATING POSITION BY LEVEL AND PROBABILITY OF A SERIOUS INJURY

SEATING POSITION	PATIENTS	AV. ISS*	PROBABILITY OF SERIOUS INJURY AIS>2	ISS>15	ISS>25
Driver	167	17.9	0.62	0.50	0.19
Front-left	66	17.0	0.58	0.45	0.24
Outboard rear	24	13.9	0.56	0.25	0.08
Centre rear	6	11.3	0.40	0.16	0
Total (Averages)	**263**	**(17.8)**	**(0.60)**	**(0.46)**	**(0.19)**

• *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 5.5
POINTS OF CONTACT FOR ALL COLLISIONS

POINTS OF CONTACT	DRIVERS(n=167) ALL (AIS>2)	FRONT LEFT(n=66) ALL (AIS>2)	REAR(n=34) ALL (AIS>2)
W'screen & header	16% (1%)	20% (5%)	6% (3%)
Steering wheel	53% (19%)	0% (0%)	0% (0%)
Steering column	10% (4%)	0% (0%)	0% (0%)
Instrument panel	49% (12%)	41% (17%)	0% (0%)
Console	8% (0%)	2% (0%)	12% (0%)
Pillars	7% (5%)	9% (3%)	3% (0%)
Side Glazing	7% (2%)	9% (0%)	6% (3%)
Door panel and rail	28% (19%)	46% (24%)	32% (18%)
Roof surfaces	4% (4%)	8% (0%)	0% (0%)
Seats	1% (0%)	2% (0%)	35% (6%)
Seat belts	49% (7%)	46% (6%)	44% (12%)
Other occupants	3% (1%)	6% (3%)	3% (0%)
Floor & toe pan	25% (8%)	12% (3%)	3% (0%)
Exterior contacts	8% (2%)	11% (6%)	15% (15%)
Non-contacts	25% (0%)	21% (5%)	27% (3%)
Average/patient	**3.9 (0.9)**	**3.3 (0.8)**	**2.9 (0.6)**

Figures for ALL contacts refer to the number of cases per 100 patients where contact was made with that particular vehicle component. Figures in parenthesis show the number of cases per 100 patients for severe injuries (AIS>2).

principal points of contact for the severe injuries to front-left passengers were the door panel and rail (24%), and the instrument panel (17%).

For rear seat passengers, the frequent contact points comprised seat belts (44%), seats (35%), door panel (32%), and non-contacts (27%), while three noteworthy severe rear seat passenger injury contacts were with the door panel and rail (18%), exterior contacts (15%), and seat belts (12%).

5.3.5 Vehicle Integrity

Table 5.6 lists the rank ordering of component intrusions into the front and rear seat occupant areas for the sample of crashes, where intrusion is defined in relation to the space inside the vehicle likely to be occupied by passengers and normally free of mechanical structures. Most noticeably, intrusions into the front seating compartment were considerably more common than rear seat intrusions for this population of crashes (2.3 cf. 0.7 intrusions per crash).

For front seat intrusions, structural components comprise the bulk of intrusions with the toe pan the most common area of deformation or intrusion, occurring in 46% of all crashes. Front door panels were the next most frequent intrusion (37%), followed by the steering assembly (31%), instrument panel (29%), A-pillars (19%), B-pillar (17%), roof (15%), roof side rail (13%), and lower side panel (13%). Rear seat intrusions mainly comprise structural deformations to neighboring components such as rear door panels 26%, roofs 13%, roof side rail (9%), B-pillars (8%), and front seat (8%).

STEERING COLUMN INTRUSIONS - Steering assembly intrusions often comprised multiple intrusions into the driver's occupant space, with roughly equal likelihood of a lateral, longitudinal and/or vertical displacement (see Table 5.6). Table 5.7 shows the longitudinal displacement of the steering column in frontal crashes, relative to estimated impact velocity of the vehicle.

The results demonstrate that the steering columns generally performed satisfactorily in the direction specified by ADR 10/01 (there were only 3 out of 123 longitudinal steering column movements that intruded into the passenger compartment beyond 127mm when the impact velocity was less than 48km/h).

SEAT AND BELT CONFIGURATIONS - Almost all front seat occupants admitted to hospital were seated in bucket seats (98%). Seat failures occurred in 34% of all cases where structural intrusions including floor pan deformations and impacts with other objects (vehicle structures or impacting object) accounted for most of these failures. Adjustable head restraints were twice as common as integral restraints in the front seat, but only half as likely to result in failure.

TABLE 5.6
RANK ORDERING OF VEHICLE DAMAGE INTRUSIONS BY FRONT AND REAR SEATING AREAS (n=227)

FRONT SEAT INTRUSIONS			REAR SEAT INTRUSIONS		
ITEM	FREQ.	(%)	ITEM	FREQ.	(%)
Toe pan	104	(46)	Door panel	58	(26)
Door panel	83	(37)	Roof surface	30	(13)
Steering assy	70	(31)	Roof side rail	21	(9)
Instrument panel	66	(29)	B-pillar	18	(8)
A-pillar	44	(19)	Front seat	17	(8)
B-pillar	39	(17)	Side panel	9	(4)
Roof surface	35	(15)	C-pillar	7	(3)
Roof side rail	30	(13)	Window frame	1	(1)
Side panel	29	(13)	Floor pan	1	(1)
Steering assy	27	(12)	A-pillar	1	(1)
Console	17	(8)			
W'screen & header	17	(8)			
Front seat	5	(2)			
Floor pan	4	(2)			
Other	12	(5)			
Totals	**512**			**163**	

STEERING ASSY MOVEMENTS BY DIRECTION OF DISPLACEMENT

Lateral	44	(19)
Vertical	39	(17)
Longitudinal	36	(16)

NB: *Steering assembly intrusions in the top part of Table 5.6 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 in the lower part of the Table.*

TABLE 5.7
LONGITUDINAL STEERING COLUMN MOVEMENT IN FRONTAL CRASHES BY IMPACT VELOCITY (DELTA-V)

	IMPACT VELOCITY (km/h)								
INTRUSION	0-16	17-32	33-48	49-64	65-80	81-96	97-112	113-128	TOTAL
none	3	19	34	27	4	1	-	-	**88**
25-75mm	-	-	1	2	3	-	-	-	**6**
75-150mm	-	-	1	4	1	1	3	1	**11**
150-300mm	-	1	2	-	2	5	-	1	**11**
>300mm	-	-	-	-	-	-	-	1	**1**
unknown	-	-	1	-	4	1	-	-	**6**
Total	**3**	**20**	**39**	**33**	**14**	**8**	**3**	**3**	**123**

5.3.6 Seat Belt Wearing

Eighty two percent of all injured occupants wore seat belts at the time of their collision. This varied from 84% for drivers, 82% for front-left passengers, and 75% for rear seat occupants. The relative difference in wearing rates between the front and rear seating positions is consistent with differences reported from exposure studies in Melbourne during 1988 (94% front seat and 66% rear seat; Vic Roads 1990).

The lower wearing rate for front seat occupants in this study (83% cf. 94%) is consistent with the argument that seat belts reduce serious injuries to vehicle occupants (it may also reflect a tendency for those not wearing seat belts to be more likely to be involved in a serious crash). However, it is impossible to make anything of the rear seat belt wearing differences because of the small numbers involved at this time.

Almost all belts inspected were retractable. Seat belt wearing behaviour was accurately reported by 87% of the occupants interviewed. Of those who gave a different version to that observed during the inspection, almost all claimed to be wearing belts when, in fact, there was no physical evidence.

POLICE REPORTED WEARING STATUS - As a test of the accuracy of police reports of seat belt wearing status, a comparison was made between what the police report claimed about wearing behaviour and what was assessed during the inspection process. These results in Table 5.8 show a 12% over-reporting rate for seat belt wearing from the police accident reports, compared to the engineer's assessment, for these 109 cases.

BELT DIFFERENCES IN THE SAMPLE - Differences in the type of crashes, impact speeds, vehicle mass and seating and patient characteristics between wearers and non-wearers are shown in Table 5.9 and subjected to statistical analysis. Care should be taken in interpreting these figures, though, because of the limited amount of data available in the sample at this time.

While impact speeds appeared to be slightly higher for belt wearers than for non-wearers, this was not statistically significant ($F(1,172)=1.3$, $p=.441$). In addition, mean vehicle mass was not statistically different between belt wearers and non-wearers ($F(1,246)=1.2$, $p=.380$). There appeared to be an over-representation of frontal impacts for non-wearers and side impacts for belt wearers. Although this finding was not statistically robust ($X^2=5.1$, $p=.16$), it is consistent with the claim that seat belts provide better protection in frontal than side impacts. Vehicle rollover was involved in only 5% of the crashed vehicles sample.

TABLE 5.8
SEAT BELT WEARING BY INSPECTED AND POLICE ACCIDENT REPORT ACCOUNTS IN THE CRASHED VEHICLE STUDY (N=109)

POLICE ACCOUNT	INVESTIGATOR ACCOUNT WEARING	INVESTIGATOR ACCOUNT NON-WEARING	**TOTAL**
WEARING	90 (83%)	13 (12%)	**103 (95%)**
NON-WEARING	1 (1%)	5 (4%)	**6 (5%)**
TOTAL	**91 (84%)**	**18 (16%)**	**109 (100%)**

NB: *The inspection process involved a very detailed examination of the seat belt mechanism, looking for physical signs of belt stretch from the crash. It is assumed that this is an accurate account of belt wearing.*

There were no substantial differences in seating position between wearers and non-wearers (X^2=1.2, p=.53). However, there were significant differences in belt wearing across the different age groups of patients (X^2=9.5, p=.05), where younger injured occupants were more likely to be unbelted and the reverse was true for older occupants. In addition, male patients were over-represented as non-wearers of seat belts compared to females (X^2=9.5, p=.002).

5.3.7 Injury and Source Analysis

As noted earlier, primary interest in the crashed vehicle study was in the unique injury and source of injury analysis available from these data. The results for the total crashed vehicle sample are shown in Tables 5.10 to 5.12.

In scoring injuries and points of contact, where there were multiple injury/source combinations for each patient (i.e., 2 head injuries to a patient from the steering wheel), only the most severe injury/source of contact was scored. However, multiple scoring was allowed per patient when different sources of injury and/or body regions were involved (i.e., 2 head injuries, 1 from the steering wheel and another from the instrument panel). This was to ensure that all unique injuries or points of contact were included in the analysis.

Thus, the table totals represent the sums of rows and columns while the total percentages refer to these sums divided by the number of patients. This means that the totals reflect multiple injuries (columns) and points of contact (rows) as allowed above for all patients (i.e., multiple scores when different body regions or points of contacts are involved).

DRIVERS - Table 5.10 shows the all injuries by contact sources for the 167 drivers where the most notable combinations were:

. chest with seat belt (35%),
. thigh/knee with instrument panel (35%),
. face with steering wheel (34%),
. lower leg with floor (25%),
. abdomen with seat belt (23%),
. head with steering wheel (19%),

TABLE 5.9
CRASH & PATIENT POPULATION CHARACTERISTICS INCLUDING DIFFERENCES BETWEEN THOSE WEARING & NOT WEARING SEAT BELTS

CHARACTERISTIC	WEARING (n=208)	NOT WEARING (n=45)	TOTAL
1. IMPACT SPEED			
Mean Delta-V	45.5km/h	45.9km/h	**45.5km/h**
Standard Deviation	24.0km/h	21.4km/h	**23.5km/h**
2. CRASH TYPE			
Frontal	60%	71%	**60%**
Side impact	37%	22%	**35%**
Rear end	0%	0%	**0%**
Rollover	3%	7%	**5%**
3. VEHICLE MASS			
Mean vehicle mass	1084kg	1096kg	**1089kg**
4. SEATING POSITION			
Driver	65%	58%	**62%**
Front-Left	25%	27%	**25%**
Rear	10%	16%	**13%**
5. PATIENT SEX			
Males	45%	70%	**49%**
Females	55%	30%	**51%**
6. PATIENT AGE			
< 17 years	8%	4%	**8%**
17 - 25 yrs	23%	44%	**27%**
26 - 55 yrs	49%	40%	**47%**
56 - 75 yrs	16%	11%	**15%**
> 75 years	4%	0%	**3%**

TABLE 5.10
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 167 DRIVERS IN ALL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	7 (1)	13				7		1	1	27 (1)
Steering Wheel	19 (7)	34 (4)	19 (8)	10 (2)		15 (3)	7 (3)		4	105 (26)
Steering Column				1 (1)		1	9 (3)	1 (1)		11 (5)
Instrument Panel	2 (1)	4	1 (1)		3 (3)	18 (2)	35 (8)	16 (2)	1 (1)	78 (17)
Console				1	1		5	2		8 (0)
Pillars	3 (1)	2			1 (1)	2 (2)	1 (1)			10 (5)
Side Glaze	4 (2)	4				4				11 (2)
Door Panel	5 (1)	1	15 (11)	8 (2)	11 (6)	14 (2)	8 (3)	4 (1)	3	69 (27)
Roof Surface	4 (3)	2				1			2 (1)	8 (4)
Seats	1		1							2 (0)
Belts			35 (4)	23 (1)	14 (1)	17	1		3 (1)	94 (7)
Other Occupant	1 (1)	1 (1)	2 (1)	1		1	1			7 (2)
Floor								25 (8)		25 (8)
Exterior	5 (2)	4	1	1		1	1	1	1 (1)	15 (2)
Non Contact	10	8		1		4		1	8	32 (0)
Other Unknown	7 (1)	8	2 (1)	4	1	16 (1)	1	2	3 (1)	43 (3)
TOTAL	66 (18)	81 (4)	76 (26)	48 (7)	30 (10)	100 (10)	68 (18)	51 (11)	26 (4)	546 (109)

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved (eg. 2 head injuries: 1 from windscreen and 1 from steering wheel).

. chest with steering wheel (19%),
. upper extremity with instrument panel (18%),
. upper extremity with seat belt (17%), and
. lower leg with instrument panel (16%).

For severe injuries only (AIS>2), the most common injury/source contacts for drivers included:
. chest with door panel (11%),
. chest with steering wheel (8%),
. thigh/knee with instrument panel (8%),
. lower leg with floor (8%), and
. head with steering wheel (7%).

FRONT-LEFT PASSENGERS - Table 5.11 shows the results for the 41 front-left seat passengers, where the 8 most common injury/source contacts were:
. chest with seat belt (41%),
. chest with door panel (27%),
. thigh/knee with instrument panel (24%),
. abdomen with seat belt (24%),
. pelvis with door panel (20%).
. lower leg with instrument panel (20%),
. upper extremity with instrument panel (18%), and
. face with windscreen/header (17%).

For severe injuries only (AIS>2) to these front seat passengers, the most common injury/source contacts included:
. chest with door panel (14%),
. pelvis with door panel (8%),
. upper extremity with instrument panel (6%),
. abdomen with door panel (6%), and
. chest with seat belt (6%).

REAR SEAT PASSENGERS - Table 5.12 shows the findings for the 23 rear seat passengers. The most common all injuries/source of contacts for these occupants were:
. abdomen with seat belt (29%),
. chest with seat belt (21%),
. upper extremity with door panel (18%),
. lower leg with seat (18%),
. abdomen with door panel (15%), and
. spine with non-contact (15%).

For severe injuries only (AIS>2) to rear seat occupants, the most common injury/source contacts included
. abdomen with seat belt (12%),
. chest with door panel (12%),
. head with exterior object (9%),
. chest with exterior object (9%), and
. abdomen with exterior object (9%).

TABLE 5.11
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 66 FRONT-LEFT SEAT PASSENGERS IN ALL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	9 (5)	17				3			2 (2)	30 (6)
Steering Wheel										0 (0)
Steering Column										0 (0)
Instrument Panel	3	6 (2)	8 (5)	3	3 (3)	18 (6)	24 (5)	20	2	86 (20)
Console					2				2	3 (0)
Pillars	6 (3)	6	2			2				15 (3)
Side Glaze	6	8								14 (0)
Door Panel		2	27 (14)	15 (6)	20 (8)	14 (2)	8 (5)	9	5 (2)	98 (35)
Roof Surface	5	5							2	11 (0)
Seats								2		2 (0)
Belts	2		41 (6)	24 (2)	5	5			3	79 (8)
Other Occupant		2		2	3 (2)	3 (2)	2		2 (2)	12 (5)
Floor								12 (3)		12 (3)
Exterior	8 (3)	5	2 (2)	2 (2)	2	6	2	2 (2)		26 (8)
Non Contact	3	6		2		3	2		9 (5)	24 (5)
Other Unknown	11 (2)	8	8 (3)	2	2	11 (2)	2	2	3	45 (6)
TOTAL	**52 (12)**	**62 (2)**	**86 (29)**	**48 (9)**	**35 (12)**	**64 (11)**	**38 (9)**	**45 (5)**	**27 (9)**	**458 (97)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved (eg. 2 face injuries; 1 from windscreen and 1 from instrument panel).

TABLE 5.12
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 34 REAR SEAT PASSENGERS IN ALL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	6 (3)					3			3	12 (3)
Steering Wheel										0 (0)
Steering Column										0 (0)
Instrument Panel										0 (0)
Console		6					3	6		15 (0)
Pillars						3				3 (0)
Side Glaze	6 (3)	6								12 (3)
Door Panel		3	12 (12)	15 (6)	12	18 (6)	6 (3)	6	6	76 (26)
Roof Surface										0 (0)
Seats		6	6	3		12 (3)	6 (3)	18	6	56 (6)
Belts			21 (6)	29 (12)	12	9			6	76 (18)
Other Occupant			3	3			3			9 (0)
Floor							3	3		6 (0)
Exterior	12 (9)	12	12 (9)	12 (9)	3 (3)	12 (3)	9 (3)	9	12	91 (35)
Non Contact	3	6				3			15 (3)	26 (3)
Other Unknown	9 (3)	9	3	3		9 (3)			3	35 (6)
TOTAL	35 (18)	47 (0)	56 (26)	65 (26)	26 (3)	68 (15)	29 (9)	41 (0)	50 (3)	418 (100)

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved.

5.3.8 Injuries By Vehicle Mass

One of the most widely recognised relationships in occupant safety is that increased vehicle mass (size) generally offers greater protection to vehicle occupants. The patient databases used here (both TAC claimants and the crashed vehicle study) did not allow this relationship to be verified for the reasons previously discussed.

There was, however, a suggestion in the mass data analysis that the types of injuries sustained by vehicle occupants in large vehicles was slightly different to those in smaller ones. Thus, it is conceivable that the injury/source contacts may also differ between occupants of small and large vehicles, which has ramifications for injury countermeasures.

An injury and source of injury analysis was, therefore, undertaken for the sample of hospitalised occupants by the size of vehicle they were travelling in.

SMALL CARS - Small cars were previously defined as having a mass of up to 1000kg). Table 5.13 shows that the most frequent body regions injured for the 77 vehicle occupants from these cars were the upper extremities, chest, face, head, and thigh/knee, while severe (AIS>2) injuries occurred in the chest, head, thigh/knee, and the pelvis. The most common points of contact included seat belts, steering wheel, door panel, and instrument panel.

The 5 most noteworthy injury/source contacts for injured occupants from small passenger cars were:

. chest with seat belt (38%),

. thigh/knee with instrument panel (30%),

. abdomen with seat belt (26%),

. face with steering wheel (22%), and

. chest with door panel (16%).

For severe (AIS>2) injuries, the most noteworthy injury/source contacts were:

. chest with door panel (10%),

. head with steering wheel (8%),

. chest with seat belt (8%), and

. thigh/knee with door panel (8%).

COMPACT CARS - Table 5.14 shows that the most frequent body regions injured for the 103 vehicle occupants in compact cars were the upper extremities, chest, face, head, and abdomen, while severe injuries occurred in the chest, head, abdomen, upper extremities, and the thigh and knee. The most common points of contact for these injuries were the seat belt, instrument panel, door panel, and the steering wheel.

The 5 most noteworthy injury/source contacts for occupants of compact vehicles were:

. chest with seat belt (34%),

. abdomen with seat belt (28%),

. thigh/knee with instrument panel (25%),

. upper extremity with instrument panel (24%), and

. face with steering wheel (21%).

For severe (AIS>2) injuries, the most noteworthy injury/source contacts were:

. chest with instrument panel (15%),

. thigh/knee with instrument panel (6%), and

. abdomen with seat belts (6%).

TABLE 5.13
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 77 SMALL CAR OCCUPANTS IN ALL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	6	12				6		1		**26 (0)**
Steering Wheel	13 (8)	22 (3)	10 (5)	4 (1)		6 (1)	5 (3)		5	**66 (21)**
Steering Column				1 (1)		1	6 (1)	1 (1)		**10 (4)**
Instrument Panel		3			4 (4)	10 (1)	30 (8)	13	1 (1)	**61 (14)**
Console				1			5	5		**12 (0)**
Pillars	5 (3)	5			1 (1)	1 (1)				**13 (5)**
Side Glaze	9 (3)	5				1				**16 (3)**
Door Panel			16 (10)	10 (3)	12 (5)	14 (3)	4	4	3	**62 (21)**
Roof Surface	3 (1)									**3 (1)**
Seats		1				3 (1)	3 (1)	1	1	**9 (3)**
Belts			38 (8)	26 (1)	13 (1)	17			5 (3)	**99 (13)**
Other Occupant	1	3	4 (1)	3		4 (1)	3		1 (1)	**18 (4)**
Floor								19 (6)		**19 (6)**
Exterior	8 (3)	5	3 (1)	3 (1)		4	1	1	1	**26 (5)**
Non Contact	4	4		1		1			8 (1)	**18 (1)**
Other Unknown	9 (1)	5	4 (3)	3		14	1	3	6	**45 (4)**
TOTAL	**58 (18)**	**65 (3)**	**74 (29)**	**52 (8)**	**30 (12)**	**84 (9)**	**58 (13)**	**49 (8)**	**32 (6)**	**504 (105)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved.

TABLE 5.14
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 103 COMPACT CAR OCCUPANTS IN ALL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	5	14				6			1	**25 (0)**
Steering Wheel	12 (4)	21 (1)	15 (5)	6 (1)		12 (3)	4 (1)		1	**70 (15)**
Steering Column							4 (3)	1 (1)		**5 (4)**
Instrument Panel	2	3 (1)	4 (2)	2	1 (1)	24 (4)	25 (6)	16 (2)	1	**78 (16)**
Console		1			1		1	1		**4 (0)**
Pillars	4 (2)	3	1							**8 (2)**
Side Glaze	2 (1)	2				3				**7 (1)**
Door Panel	3 (1)	3	18 (15)	9 (4)	13 (2)	13 (2)	6 (2)	7 (1)	4 (1)	**75 (27)**
Roof Surface	3 (3)	2				1			1 (1)	**7 (4)**
Seats	2	1	2	1		1		4		**11 (0)**
Belts			34 (5)	28 (6)	10	9	2		2	**84 (11)**
Other Occupant	1 (1)	1 (1)	1 (1)	1	1 (1)		1			**6 (4)**
Floor							1	17 (3)		**18 (3)**
Exterior	9 (6)	9	6 (4)	5 (4)	2 (1)	7 (1)	4 (1)	4 (1)	5 (1)	**50 (18)**
Non Contact	11	9		2		2			12 (2)	**35 (2)**
Other Unknown	8 (2)	12	3	4	1	14 (3)	1	1	2 (1)	**45 (6)**
TOTAL	**60 (19)**	**80 (3)**	**83 (31)**	**57 (15)**	**28 (5)**	**90 (13)**	**49 (13)**	**50 (8)**	**28 (6)**	**526 (112)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2) Multiple injuries are included where separate injury sources were involved.

TABLE 5.15
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 76 LARGE CAR OCCUPANTS IN ALL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	9 (7)	12				4			3 (1)	**28 (8)**
Steering Wheel	12 (1)	22 (4)	9 (4)	8 (1)		8 (1)	3 (3)		1	**63 (14)**
Steering Column							8 (1)			**8 (1)**
Instrument Panel	4 (1)	7	3 (3)		4 (4)	11 (3)	32 (7)	18 (1)	1 (1)	**79 (20)**
Console		1			1		4	1	1	**9 (0)**
Pillars	1	1				7 (4)	3 (3)			**12 (7)**
Side Glaze	3 (1)	5				1				**9 (1)**
Door Panel	7 (1)	1	18 (9)	13 (5)	17 (11)	16 (3)	14 (11)	4	5	**96 (39)**
Roof Surface	4 (1)	4							4	**12 (1)**
Seats			1			1		3	1	**7 (0)**
Belts	1		34 (1)	20	13	14			4	**87 (1)**
Other Occupant			1		1	1				**4 (0)**
Floor								24 (9)		**24 (9)**
Exterior	3	1				1			1	**7 (0)**
Non Contact	7	8				7	1		7	**29 (0)**
Other Unknown	8	8	4 (1)	3		13		1		**37 (1)**
TOTAL	**58 (13)**	**71 (4)**	**71 (18)**	**43 (7)**	**37 (14)**	**84 (11)**	**64 (24)**	**51 (11)**	**29 (3)**	**509 (104)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved.

LARGE CARS - Table 5.15 illustrates that the most frequent body regions injured for occupants of large cars included the upper extremities, chest, face, thigh/knee, and head, while severe injuries occurred in the thigh/knee, chest, pelvis, and the head. The most common points of contacts were the door panel, seat belts, instrument panel, and the steering wheel.

The 5 most noteworthy injury/source contacts for occupants of large vehicles were:

. chest with seat belt (34%),

. thigh/knee with instrument panel (32%),

. lower leg with floor (24%),

. face with steering wheel (22%), and

. abdomen with seat belt (20%).

For severe (AIS>2) injuries, the most noteworthy injury/source contacts were:

. pelvis with door panel (11%),

. thigh/knee with door panel (11%),

. chest with door panel (9%), and

. lower leg with floor (9%).

5.3.9 All Collision Summary

There were many interesting findings for the total sample of vehicles inspected. The majority of occupants were hospitalised from crashes involving impact speeds less than 48km/h (30mph). The types of crashes in this hospital sample over-emphasised side impacts and under-stated rear enders, compared to what was expected from mass data statistics.

Small cars were under-represented and large cars, over-represented, while young occupants and males were also slightly over-involved in the sample of crashes. Not surprisingly, non-wearers of seat belts were twice as likely to be injured as belt wearers.

In terms of types of injuries and the sources of these injuries, door panels and seat belts were most frequently associated with occupant injuries to both front and rear seat occupants of cars, predominantly involving injury to the chest, abdomen, pelvis, and the upper and lower extremities.

Seat belts were especially associated with frequent severe injuries to the abdomen and chest for all seating positions. Drivers were particularly at risk of injury to chest, head, and face from the steering wheel. Lower extremity injuries were linked to the instrument panel and the floor for all front seat occupants. In addition, rear seat passengers were somewhat vulnerable to whiplash injuries and to contacts with exterior objects.

These findings are confounded by the different types of impact directions and crash severities in the total study sample of vehicles inspected. As the prime purpose of this study is to identify the main causes of injury to vehicle occupants and potential countermeasures, it is essential to break down the injury/source contacts by type of crash. Once again, it must be stressed that the cell sizes reduce markedly in many of these analyses and care should be taken in interpreting these results.

There was a hint in the vehicle size analysis that larger vehicle occupants had slightly fewer chest injuries and marginally more upper extremity injuries than smaller vehicle occupants. This could be a function of the over-representation of females in smaller vehicles (male drivers tend to sit further away from the steering column than female drivers, hence less likely to sustain a injury to the chest).

5.4 FRONTAL CRASHES

Frontal collisions were the most common type of impact experienced by vehicle occupants in the mass data analysis (65%) and in the crashed vehicle study (60%). This type of crash, therefore, deserves primary focus in occupant protection. Moreover, seat belts are most likely to be of maximum benefit for occupants involved in these collisions.

5.4.1 Frontal Crash Configurations

These data are more reliable at this time because of the larger number of frontal crash cases examined. To date, there are details available on 134 crashes involving 161 hospitalised occupants. Figure 5.3 shows the summary of the types of frontal crashes observed in the crashed vehicle study.

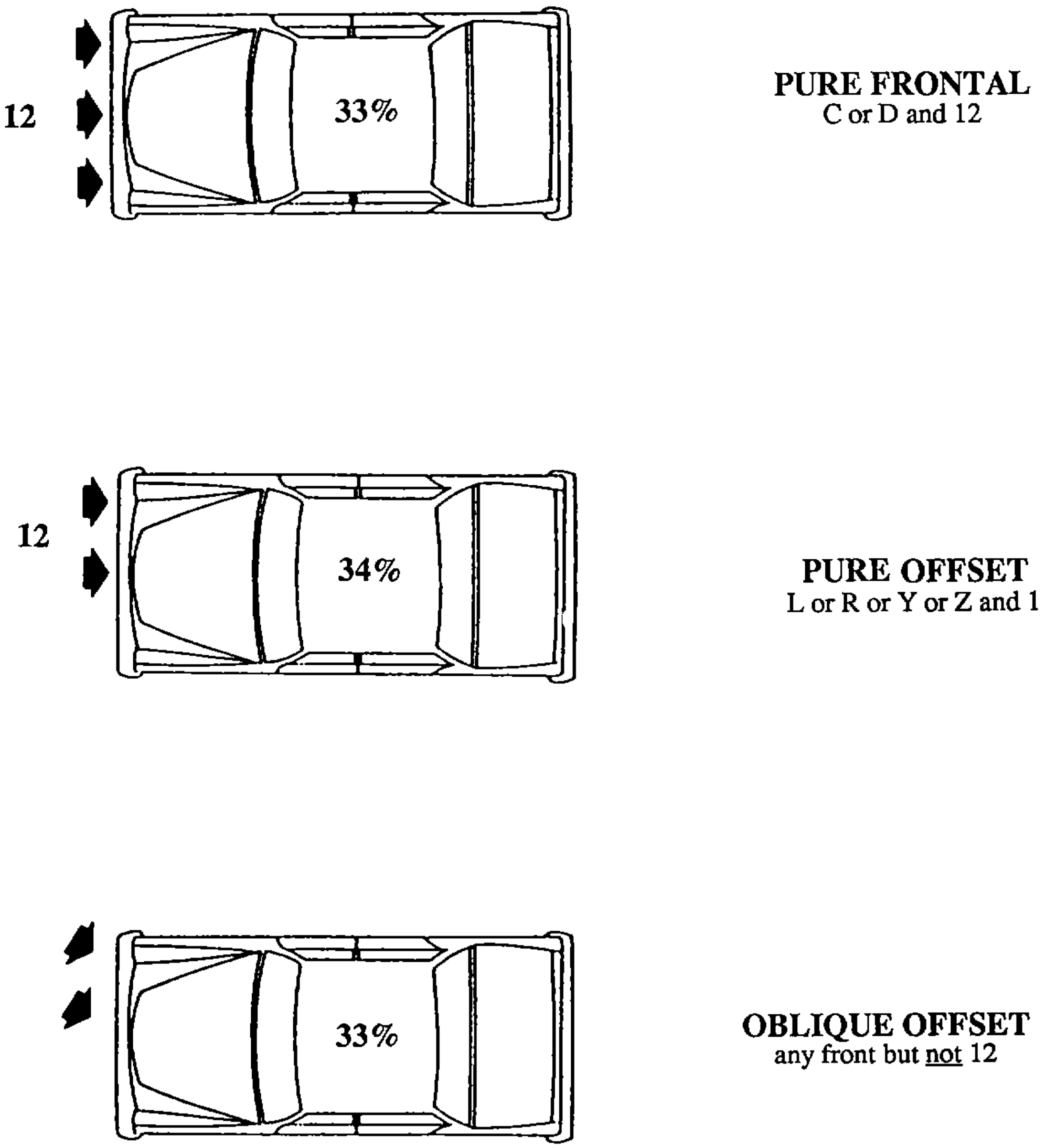


Figure 5.3 *Analysis of the various frontal crash configurations observed in the sample of crashed vehicles inspected to date.*

TABLE 5.16
RANK ORDERING OF VEHICLE DAMAGE INTRUSIONS FOR FRONTAL CRASHES BY FRONT AND REAR SEATING AREAS (n=134)

FRONT SEAT INTRUSIONS			REAR SEAT INTRUSIONS		
ITEM	FREQ.	(%)	ITEM	FREQ.	(%)
Toe pan	100	(75)	Door panel	7	(5)
Instrument panel	61	(46)	Front seat	6	(5)
Steering assy	23	(17)	Roof	3	(2)
Side panel	15	(11)	B-pillar	3	(2)
A-pillar	14	(10)	Roof side rail	1	(1)
Console	13	(10)			
Door panel	10	(8)			
Roof	6	(5)			
Windscreen/header	6	(5)			
Lower dash	3	(2)			
B-pillar	3	(2)			
Floor pan	2	(2)			
Roof side rail	1	(1)			
Other	6	(5)			
Totals	**263**			**20**	

STEERING ASSY MOVEMENTS BY DIRECTION OF DISPLACEMENT

Longitudinal	33	(25)
Lateral	26	(19)
Vertical	25	(19)

NB: *Steering assembly intrusions in the top part of Table 5.11 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 in the lower part of the Table.*

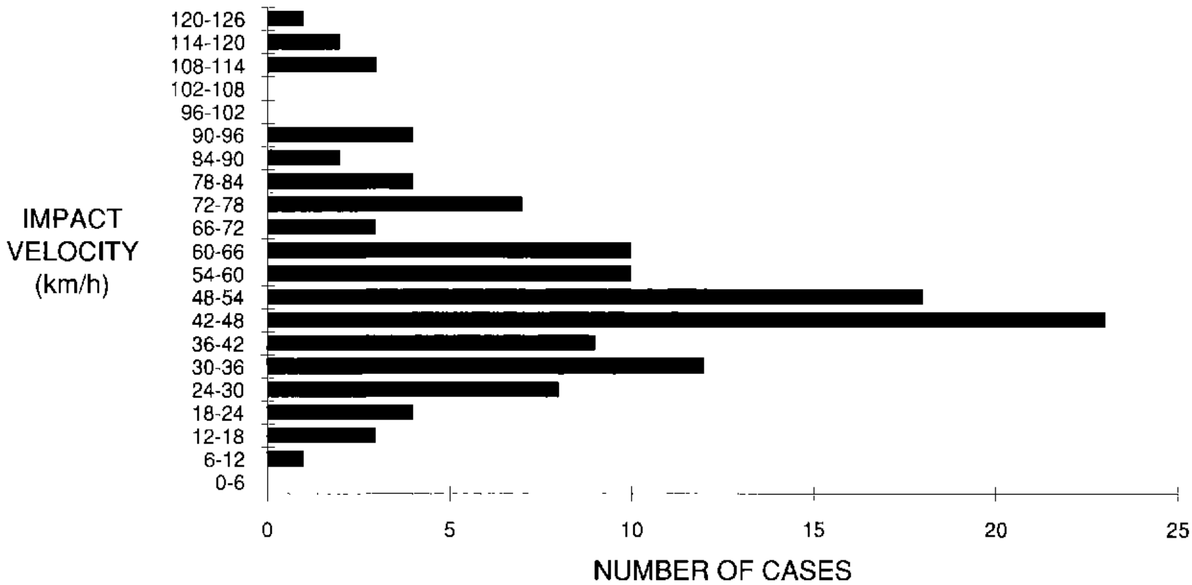
Pure frontals were defined as those involving a perpendicular impact direction and a central or full impact location (clock-face 12 and a F/C or F/D body region assessment in the NASS configuration described in Figure 5.1). Pure offset was a frontal perpendicular crash involving a partial front impact (clock-face 12 and an L or R or Y or Z location), while an oblique offset was a non-perpendicular, partial front impact (clock-face not 12 and any front impact).

There were roughly equal numbers and proportions of crashes in each of these three frontal crash configurations.

5.4.2 Impact Velocity

Figure 5.4 shows the frequency distribution of estimated impact velocity observed in the sample of frontal crashes inspected. The modal value was between 42 and 48km/h with a range of impact speeds from 6 to 126km/h. Roughly half of all delta-V values were equal to or below 48km/h (30mph).

Figure 5.4 Frequency histogram of impact velocities (delta-V) observed for the frontal crash sample of vehicles inspected to date.



5.4.3 Intrusions and Deformations

Table 5.16 lists the rank ordering of component intrusions into the front and rear seat occupant areas for the total sample of frontal crashes. Most noticeably, intrusions into the front seating compartment were again more common than rear seat intrusions for these frontal crashes (2.0 cf., 0.2 intrusions per crash).

For front seat intrusions, structural components again comprise the bulk of intrusions with the toe pan the most common area of deformation or intrusion, occurring in 75% of frontal crashes. The instrument panel was the next most frequent intrusion member (46%), followed by the steering assembly (17%), side panel (11%), A-pillars (10%), and console (10%).

Steering assembly intrusions often comprised multiple intrusions into the driver's occupant space, with roughly equal likelihood of a lateral, longitudinal and/or vertical displacement. Rear seat intrusions mainly comprise deformations to the door panel (5%) and front seat (5%).

FRONT- VERSUS REAR-WHEEL DRIVE - To test whether the drive configuration had any effect on vehicle damage in frontal crashes, the frontal intrusion and deformation analysis was repeated contrasting front- with rear-wheel drive vehicles. The mass data analysis in Chapter 3 earlier showed that drive configuration was intimately related to vehicle size. In addition, intrusions are also likely to be a function of impact velocity. Hence, there was a need to contrast the two drive configurations in a more controlled setting to permit a more meaningful comparison.

The mass data showed that compact vehicles was the one vehicle size category where there were roughly equal proportions of front- and rear-wheel drive configurations. In the crashed vehicle study sample, there were 47 cases involving compact vehicles of which 19 were front-wheel drive and 28 were rear-wheel drive. Moreover, detailed examination revealed that there were roughly equal proportions of impact velocities below and above 45km/h in both these drive configurations. Hence, this appeared to be a suitable vehicle size category in which to conduct this analysis.

Table 5.17 contrasts the vehicle front seating compartment intrusions and deformations for compact vehicles involved in frontal crashes in the crashed vehicle study sample.

TABLE 5.17
VEHICLE DAMAGE INTRUSIONS FOR FRONT SEAT OCCUPANTS IN COMPACT VEHICLES INVOLVED IN FRONTAL CRASHES BY FRONT AND REAR WHEEL DRIVE CONFIGURATION

FRONT-WHEEL DRIVE (n=19)			**REAR-WHEEL DRIVE (n=28)**		
ITEM	FREQ.	(%)	ITEM	FREQ.	(%)
Toe pan	13	(68)	Toe pan	25	(89)
Instrument panel	7	(37)	Instrument panel	15	(54)
Steering assy	6	(32)	Steering column	13	(46)
Door panel	2	(11)	Console	7	(25)
B-pillar	1	(5)	Side panel	4	(14)
Console	1	(5)	Roof	2	(7)
			Door panel	1	(4)
			Lower dash	1	(4)
			Windscreen/header	1	(4)
			Other	2	(7)
Totals	**30**			**71**	

STEERING ASSY MOVEMENTS BY DIRECTION OF DISPLACEMENT

Longitudinal	4	(21)	Longitudinal	11	(39)
Lateral	4	(21)	Lateral	5	(18)
Vertical	3	(16)	Vertical	6	(21)

1. Steering assembly intrusions in the top part of Table 5.12 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 in the lower part of the Table.

2. Vehicle intrusions controlled for vehicle size and impact velocity, thereby enabling a true comparison of the drive configuration effect on vehicle intrusions and deformations

The number of intrusions was markedly more for rear- than front-wheel drive (2.5 cf. 1.6 intrusions per crash). Moreover, there were proportionally more intrusions involving the toe pan, instrument panel and steering assembly for rear-wheel drive configurations. Importantly, also, there were approximately twice as many longitudinal movements of the steering column relative to lateral and vertical movements in rear-wheel drive cars than there were in front-wheel drive cars. Given the relatively small numbers of intrusion cases available at this time, care should be taken not to interpret too much on these findings at this stage.

5.4.4 Ejections and Entrapments

The number of occupants who were ejected or entrapped in their vehicles in frontal crashes is shown in Tables 5.18 and 5.19. Wearing seat belts did not appear to unduly influence the incidence of vehicle entrapment; 71% of belted and 72% of unbelted occupants were not entrapped in their vehicle at the time of collision. While partial entrapments were marginally higher for belt wearers than non-wearers, this appears to be a function of the greater inability to assign entrapment status to non-belt wearers at the time of collision.

For ejections in Table 5.19, belt wearing appears to have been of benefit in preventing ejections. There were no recorded cases of ejections amongst belt wearers in the sample, compared to the 12% or so of unbelted occupants who were ejected from their vehicle during the frontal crash.

5.4.5 Injury and Source Analysis

As noted earlier, the real value of the follow-up study of crashed vehicles was in the ability to assign vehicle contact points to the occupant injuries (not available from mass data analyses). The findings for the sample of frontal crashes by seating position and belt wearing is described below in Tables 5.20 to 5.26. As in the previous section, scoring of injuries and points of contact were allowed for multiple injury/source combinations for each patient, providing they were unique.

DRIVERS - Table 5.20 shows the rates of injuries (all injuries and severe injuries only) and points of contact inside the vehicle for the 107 drivers involved in frontal collisions. The most frequent body regions injured for these occupants were the upper limbs, face, chest, thigh and knee, lower leg, and the head, while for severe injuries (AIS>2), the most common injuries occurred to the chest, thigh and knee, lower leg, and the head.

Common points of contact for all and severe injuries to drivers inside the vehicle included the steering wheel, instrument panel, seat belts, and the floor.

For all injuries to drivers in frontal crashes, the 5 most frequent injury/source contacts were:

- . face with steering wheel (51%),
- . thigh/knee with instrument panel (46%),
- . chest with seat belt (45%),
- . lower leg with floor (37%), and
- . head with steering wheel (28%).

while for severe injury/source contacts, they were:

- . chest with steering wheel (12%),
- . lower leg with floor (11%),
- . head with steering wheel (10%),
- . thigh/knee with instrument panel (10%), and
- . chest with seat belt (6%).

Seat Belt Wearing Differences - Tables 5.21 and 5.22 show the findings for injuries and contact sources for drivers by whether they were restrained or not. For the 81 belted drivers, in Table 5.21, there were no appreciable differences in the pattern of results to those described above for all drivers. The unbelted results, though, were quite different and are described below.

Table 5.22 shows that the most frequent body regions injured for these 21 unrestrained drivers comprised the face, head, and upper and lower extremities, while for severe injuries (AIS>2), the most common injuries occurred to the legs, thigh and knees, abdomen, chest, and the head.

TABLE 5.18
ENTRAPMENT ANALYSIS FOR BELTED AND UNBELTED OCCUPANTS INVOLVED IN FRONTAL CRASHES (n=155)

ENTRAPMENTS	BELTED		UNBELTED	
	FREQ.	(%)	FREQ.	(%)
No entrapment	87	(71%)	23	(72%)
Full entrapment	5	(4%)	2	(6%)
Partial entrapment	20	(16%)	2	(6%)
Unknown	11	(9%)	5	(16%)
Total	**123**	**(100%)**	**32**	**(100%)**

TABLE 5.19
EJECTION ANALYSIS FOR BELTED AND UNBELTED OCCUPANTS INVOLVED IN FRONTAL CRASHES (n=155)

EJECTIONS	BELTED		UNBELTED	
	FREQ.	(%)	FREQ.	(%)
No ejection	123	(100%)	27	(84%)
Full ejection	0	(0%)	3	(9%)
Partial ejection	0	(0%)	1	(3%)
Unknown	0	(0%)	1	(3%)
Total	**123**	**(100%)**	**32**	**(100%)**

Common points of contact for all and severe injuries to unrestrained drivers inside the vehicle included the steering wheel, instrument panel, windscreen and header, exterior contacts, and the floor (there was a noticeable increase in contacts with the windscreen and header and exterior objects for these unrestrained occupants).

For all injuries to unrestrained drivers, the 5 most frequent injury/source contacts were:

. face with windscreen/header (48%),
. chest with steering wheel (38%),
. thigh/knee with instrument panel (38%),
. lower leg with floor (37%), and
. head with windscreen/header (29%).

TABLE 5.20
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 107 DRIVERS IN FRONTAL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	9 (1)	19				8		1	1	**38 (1)**
Steering Wheel	28 (10)	51 (6)	27 (12)	12 (4)		20 (5)	9 (5)		6	**153 (41)**
Steering Column				1 (1)		1	12 (4)	2 (2)		**16 (7)**
Instrument Panel	3 (1)	6			4 (4)	25 (3)	46 (10)	18 (2)	2 (2)	**103 (21)**
Console							4	2		**6 (0)**
Pillars	3	3			1 (1)	4 (4)	2 (2)			**12 (7)**
Side Glaze		1				4				**5 (0)**
Door Panel	1 (1)		4 (3)	1 (1)	1 (1)	2 (1)	1	1		**10 (7)**
Roof Surface										**0 (0)**
Seats										**0 (0)**
Belts			45 (6)	22 (2)	16	19	1		2 (2)	**105 (9)**
Other Occupant						1				**1 (0)**
Floor								37 (11)		**37 (11)**
Exterior	3 (1)	3	2	1		1	1		2 (1)	**12 (2)**
Non Contact	11	7		2		3			9	**32 (0)**
Other Unknown	3	6	1	1		12 (1)		1	1	**24 (1)**
TOTAL	**61 (14)**	**94 (6)**	**79 (21)**	**40 (7)**	**21 (6)**	**99 (13)**	**76 (21)**	**62 (15)**	**22 (5)**	**554 (107)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved.

TABLE 5.21
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 81 BELTED DRIVERS IN FRONTAL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	4 (1)	10				6				**20 (1)**
Steering Wheel	32 (11)	58 (6)	25 (12)	7 (2)		23 (5)	10 (5)		5	**160 (42)**
Steering Column				1 (1)		1	14 (4)	1 (1)		**17 (6)**
Instrument Panel	2 (1)	5			4 (4)	25 (4)	47 (10)	15 (1)	2 (2)	**100 (22)**
Console							4	1		**5 (0)**
Pillars	2	2			1 (1)	5 (5)	2 (2)			**14 (9)**
Side Glaze						5				**5 (0)**
Door Panel			5 (4)	1 (1)	1 (1)	1 (1)	1	1		**11 (7)**
Roof Surface										**0 (0)**
Seats										**0 (0)**
Belts			58 (7)	30 (2)	21	25	1		2 (2)	**137 (12)**
Other Occupant						1				**1 (0)**
Floor								38 (12)		**38 (12)**
Exterior	1 (1)	2	1						1 (1)	**6 (2)**
Non Contact	14	9		1		2			11	**37 (0)**
Other Unknown	2	6	1	1		12		1	1	**26 (0)**
TOTAL	**58 (15)**	**93 (6)**	**90 (23)**	**42 (7)**	**27 (6)**	**107 (15)**	**79 (21)**	**58 (15)**	**23 (6)**	**578 (115)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved.

TABLE 5.22
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 21 UNBELTED DRIVERS IN FRONTAL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	29	48				19		5	5	**105 (0)**
Steering Wheel	19 (10)	29 (5)	38 (10)	29 (10)		5 (5)	10 (5)		10	**138 (43)**
Steering Column							10 (5)	5 (5)		**14 (10)**
Instrument Panel		5			5 (5)	29	38 (5)	29 (5)		**105 (14)**
Console							5			**5 (0)**
Pillars	5	5								**10 (0)**
Side Glaze		5								**5 (0)**
Door Panel						5				**5 (0)**
Roof Surface										**0 (0)**
Seats										**0 (0)**
Belts										**0 (0)**
Other Occupant										**0 (0)**
Floor								33 (10)		**33 (10)**
Exterior	10	5	5	5		5	5		5	**38 (0)**
Non Contact	5									**5 (0)**
Other Unknown	5	5				10				**19 (0)**
TOTAL	**71 (10)**	**100 (5)**	**43 (10)**	**33 (10)**	**5 (5)**	**71 (5)**	**67 (14)**	**71 (19)**	**19 (0)**	**481 (76)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2) Multiple injuries are included where separate injury sources were involved.

while for severe injuries (AIS>2), the most frequent injury/source contacts for unbelted drivers included:

. head with steering wheel (10%),

. chest with steering wheel (10%),

. abdomen with steering wheel (10%), and

. lower leg with floor (10%).

FRONT-LEFT PASSENGERS - Table 5.23 shows the injuries and points of contact inside the vehicle for the 35 front-left seat passengers involved in frontal collisions for all and severe injuries.

The most frequent body regions injured for these occupants comprised the upper extremity, chest, face, lower leg, and head, while severe injuries (AIS>2) occurred to the chest, upper extremities, thigh and knees, and the spine. Common points of contact for all and severe injuries to front-left passengers in frontal crashes included the instrument panel, seat belts, and the windscreen and header.

The 5 most noteworthy injury/source contacts for all injuries to front-left passengers in frontal crashes were:

. chest with seat belt (49%),

. upper extremity with instrument panel (32%),

. thigh/knee with the instrument panel (32%),

. lower leg with the instrument panel (30%),

. face with windscreen/header (27%), and

. abdomen with seat belt (27%).

while for severe front-left passenger injuries, the most noteworthy injury/source contacts were:

. upper extremity with instrument panel (11%),

. chest with seat belt (11%), and

. thigh/knee with instrument panel (8%).

Seat Belt Wearing Differences - Tables 5.24 and 5.25 further show the findings for injuries and contact sources for front-left seat passengers by whether they were restrained or not.

For the 28 belted front-left passengers, in Table 5.24, there were no marked differences in the pattern of results to those described above for all these occupants (except for a slight increase in the prevalence of spinal injuries). However, the findings for unbelted front-left passengers in Table 5.25 were noticeably different and are described in detail below.

The most frequent body regions injured for the 7 unrestrained front-left seat occupants were the face, upper extremities, head, and lower extremities, while for severe injuries (AIS>2), the most common injuries occurred to the upper extremities, head, chest, pelvis, thigh and knees, and the lower leg. Common points of contact for all and severe injuries to front-left passengers inside the vehicle included the instrument panel, windscreen and header, and exterior contacts (there was a noticeable increase in the rate of these contacts for unrestrained compared with restrained occupants).

The 5 most noteworthy injury/source contacts for all injuries to unbelted front-left passengers included:

. face and windscreen/header (71%),

. thigh/knee with instrument panel (57%),

. head with windscreen/header (43%),

. chest with instrument panel (43%), and

. upper extremity with instrument panel (43%).

For severe injuries to these unrestrained occupants, the most noticeable injury/source contacts included:

TABLE 5.23
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY
FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY
FOR 35 FRONT-LEFT SEAT PASSENGERS IN FRONTAL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	14 (5)	27				5			3 (3)	49 (8)
Steering Wheel										0 (0)
Steering Column										0 (0)
Instrument Panel	5	8 (3)	11 (5)	5	5 (5)	32 (11)	32 (8)	30	3	132 (32)
Console					3				3	5 (0)
Pillars	5 (3)	5								11 (3)
Side Glaze		3								3 (0)
Door Panel			3	3	3 (3)	8	3 (3)	3		22 (5)
Roof Surface	3									3 (0)
Seats										0 (0)
Belts	3		49 (11)	27 (3)	3	8			5	95 (14)
Other Occupant		3			3	5 (3)			3 (3)	14 (5)
Floor								22 (5)		22 (5)
Exterior	3	3			3	5	3	3 (3)		19 (3)
Non Contact	3	8		3		3			14 (5)	30 (5)
Other Unknown	5	8	5	3		14 (3)	3		5	43 (3)
TOTAL	**41 (8)**	**65 (3)**	**68 (16)**	**41 (3)**	**19 (8)**	**81 (16)**	**41 (11)**	**57 (8)**	**35 (11)**	**446 (84)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved

TABLE 5.24
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 28 BELTED FRONT-LEFT SEAT PASSENGERS IN FRONTAL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	7 (4)	18				4			4 (4)	**32 (7)**
Steering Wheel										**0 (0)**
Steering Column										**0 (0)**
Instrument Panel	4	7 (4)	4 (4)	4	4 (4)	32 (7)	29 (7)	32	4	**118 (25)**
Console					4				4	**7 (0)**
Pillars	7 (4)	7								**14 (4)**
Side Glaze		4								**4 (0)**
Door Panel			4	4	4 (4)	7	4 (4)	4		**25 (7)**
Roof Surface	4									**4 (0)**
Seats										**0 (0)**
Belts	4		64 (14)	36 (4)	4	11			7	**125 (18)**
Other Occupant		4			4	7 (4)			4 (4)	**18 (7)**
Floor								25 (7)		**25 (7)**
Exterior										**0 (0)**
Non Contact	4	7		4		4			18 (7)	**36 (7)**
Other Unknown	7	11	7	4		14	4		7	**54 (0)**
TOTAL	**36 (7)**	**57 (4)**	**79 (18)**	**50 (4)**	**18 (7)**	**79 (11)**	**36 (11)**	**61 (7)**	**46 (14)**	**461 (82)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved.

TABLE 5.25
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 7 UNBELTED FRONT-LEFT SEAT PASSENGERS IN FRONTAL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	43 (14)	71				14				129 (14)
Steering Wheel										0 (0)
Steering Column										0 (0)
Instrument Panel	14	14	43 (14)	14	14 (14)	43 (29)	57 (14)	29		229 (71)
Console										0 (0)
Pillars										0 (0)
Side Glaze										0 (0)
Door Panel						14				14 (0)
Roof Surface										0 (0)
Seats										0 (0)
Belts										0 (0)
Other Occupant										0 (0)
Floor								14		14 (0)
Exterior	14	14			14	29	14	14 (14)		100 (14)
Non Contact		14								14 (0)
Other Unknown						14 (14)				14 (14)
TOTAL	71 (14)	114 (0)	43 (14)	14 (0)	29 (14)	114 (43)	71 (14)	57 (14)	0 (0)	514 (114)

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved.

. upper extremity with instrument panel (29%),
. head with windscreen/header (14%),
. chest with instrument panel (14%),
. pelvis with instrument panel (14%), and
. thigh/knee with instrument panel (14%).

It must be stressed that these findings were derived from only seven patients in total and, therefore, must be viewed as preliminary findings at this stage.

REAR SEAT PASSENGERS - Table 5.26 shows the injuries (all and severe) and points of contact inside the vehicle for the 19 rear seat passengers involved in frontal collisions.

The most frequent body regions injured for these occupants were the abdomen, upper limbs, spine, chest, and lower leg, while for severe injuries (AIS>2), the most common injuries occurred to the abdomen, head, chest, upper extremity, and the thigh and knee. The only two noteworthy points of contact for all and severe injuries to rear seat passengers included the seat belts and the front seats.

The 5 most frequent all injury/source contacts were:

. abdomen with seat belt (53%),
. chest with seat belt (32%),
. lower leg with seat (26%),
. spine with non-contact (26%), and
. upper extremity with seat (21%).

while the most frequent severe (AIS>2) injury/source contacts for these occupants were:

. abdomen with seat belt (21%), and
. chest with seat belt (11%).

5.4.6 Frontal Crash Summary

The results of the front impact analysis were slightly different to those reported earlier for all collisions. The modal impact delta-V was higher for frontal crashes only while roughly half the cases inspected had delta-V values below 48km/h. There were equal numbers of pure frontals, perpendicular offsets, and oblique offset collisions.

Frontal intrusions were again more prevalent than rear intrusions and there were equal numbers of longitudinal, lateral, and vertical steering column intrusions. Rear-wheel drive compact vehicles experienced more front compartment intrusions than did front-wheel drive compacts and there was a disproportionate number of longitudinal intrusions of the steering column in rear-wheel drive, than front-wheel drive, vehicles.

Three-quarters of all frontal crashes experienced no occupant entrapments, and there were no apparent differences in the rate of entrapments between belt wearers and non-wearers. There were no cases of occupant ejections amongst belt wearers and between 12 and 16 percent amongst non-wearers.

Front seat occupants sustained considerable numbers of body injuries (including both minor and serious injury) to their heads, chests, abdomens, and lower extremities from contacts with the steering wheel, seat belts, instrument panels, and windscreen and header. Occupants not wearing seat belts sustained more head, face and upper extremity injuries and more contacts with the windscreen and header, and exterior objects.

5.5 SIDE IMPACT COLLISIONS

As noted earlier, this initial report on the findings of the crashed vehicle study is primarily concerned with **front seat occupants in frontal crashes**. While the number of cases is still too small to provide a definitive analysis of side impacts, nevertheless, a preliminary description of the 80 cases so far inspected is warranted here.

TABLE 5.26
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 19 REAR SEAT PASSENGERS IN FRONTAL COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	11 (5)					5			5	21 (5)
Steering Wheel										0 (0)
Steering Column										0 (0)
Instrument Panel										0 (0)
Console		11					5	11		26 (0)
Pillars						5				5 (0)
Side Glaze										0 (0)
Door Panel				5		5 (5)	5 (5)		5	21 (11)
Roof Surface										0 (0)
Seats		11	11	5		21 (5)	11 (5)	26	11	95 (11)
Belts			32 (11)	53 (21)	16	11			11	121 (32)
Other Occupant			5	5			5			16 (0)
Floor										0 (0)
Exterior										0 (0)
Non Contact						5			26 (5)	32 (5)
Other Unknown	11 (5)	16	5	5		11			5	53 (5)
TOTAL	21 (11)	37 (0)	53 (11)	74 (21)	16 (0)	63 (11)	26 (11)	37 (0)	63 (5)	389 (68)

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved.

Side impacts were involved in 14% of TAC hospitalised injury claims from 1983 until 1988 and accounted for 35% of the patient population included in the crashed vehicle study. This type of crash is also usually more severe to the occupants than either a front or a rear impact crash, especially those on the "near" (impacted) side. As injury countermeasures are likely to be quite different for this group of crashes, they need to be considered separately.

This analysis was not especially concerned with seat belt effects in side impacts as they are not expected to have much benefit to occupants in this crash configuration (other than in entrapment or ejection analysis). Moreover, preliminary analysis revealed practically no difference in the patterns of injuries or contacts between wearers and non-wearers. However, there were noticeable injury and contact differences between seating position, and for drivers only, by whether the vehicle was impacted in the "near" or "far" side. This section examines the injury/source contacts for drivers, front-left seat and rear seat passengers involved in side impact collisions.

5.5.1 Side Impact Configurations

Side impacted regions for passenger cars were analysed in terms of the impact zone, relative to the passenger compartment, and angle of impact, and the results are shown in Figure 5.5. Pure compartment impacts were defined as those where the bullet vehicle impacted only the cabin (section P on the NASS diagram described in Figure 5.1), while pure non-compartment impacts were those where the impact zone was either the front or rear of the vehicle (sections F or B). Compartment involvement comprised all other side impact regions (sections D, Y, or Z). Angle of impact was either perpendicular (clock-face 3 or 9) or oblique (clock-face 1, 2, 4, 5, 7, 8, 10, or 11).

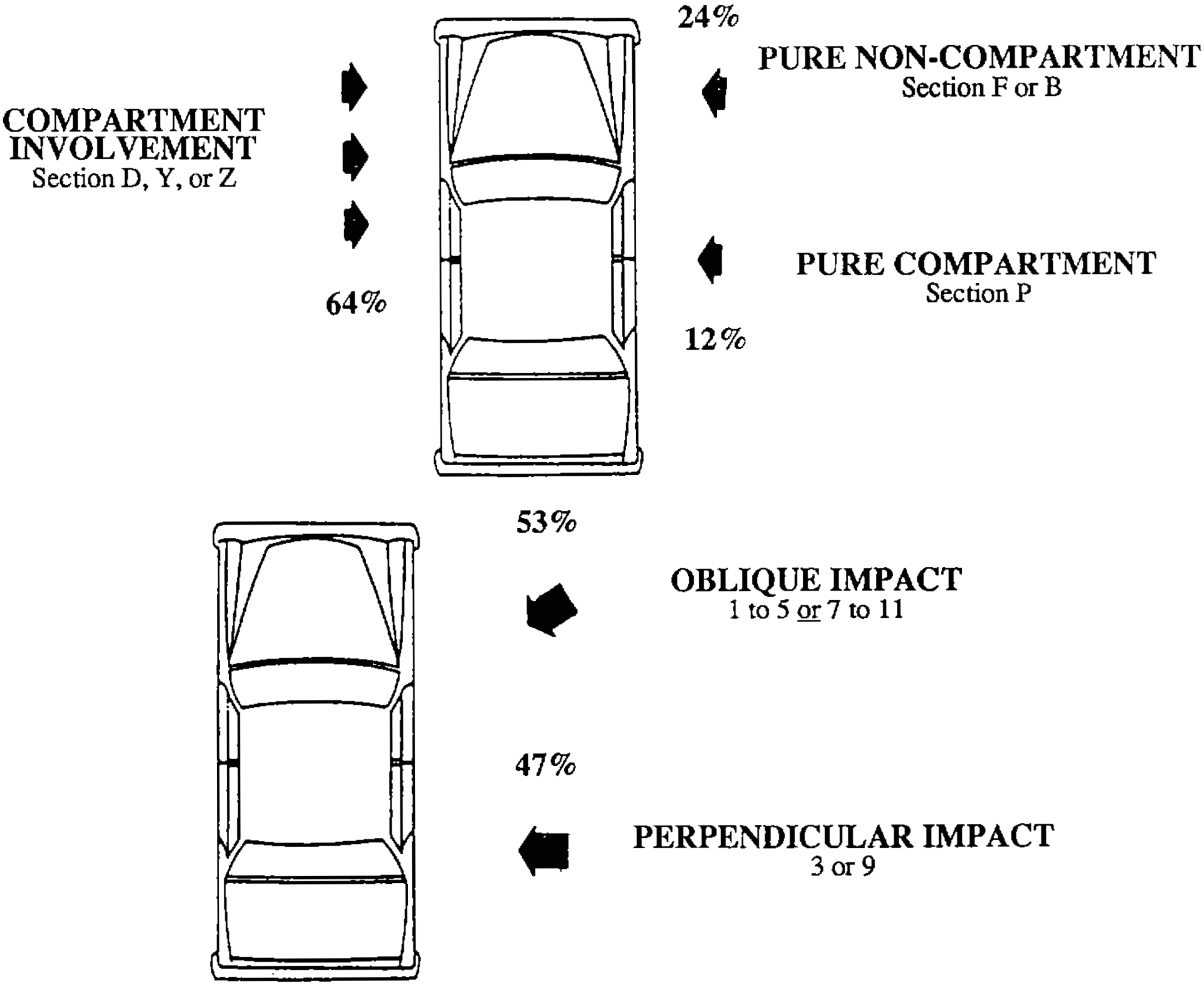


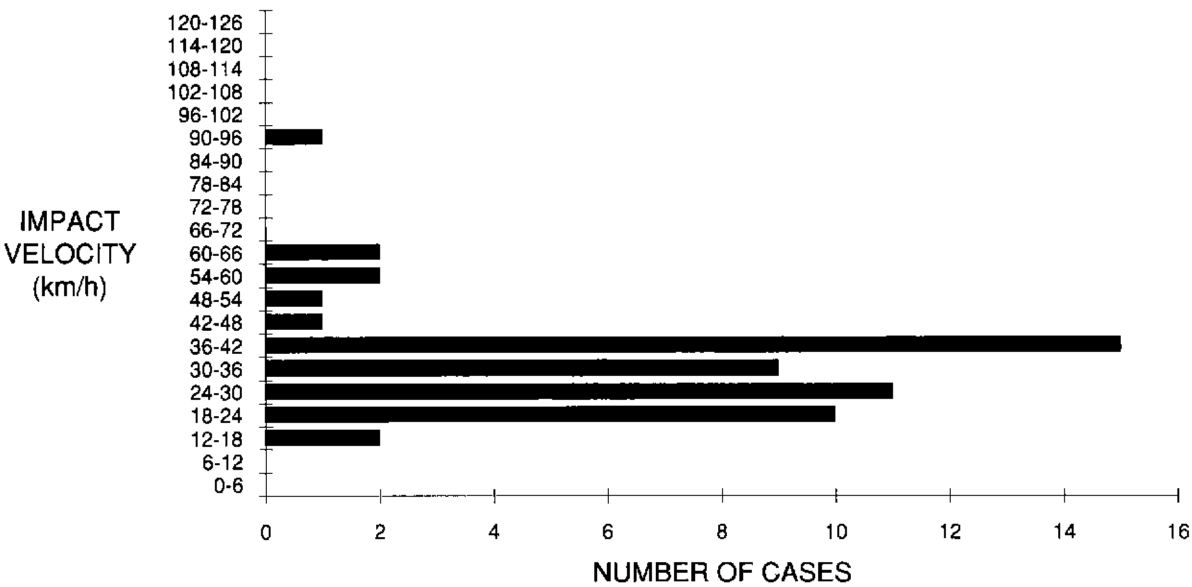
Figure 5.5 Analysis of the various side impacted regions of the vehicles observed in the sample of crashed vehicles inspected to date.

The results in Figure 5.5 show that the passenger compartment was fully or partially impacted in roughly three-quarters of all side impacts. Moreover, impact direction was approximately evenly divided between perpendicular and oblique impacts.

5.5.2 Side Impact Velocity

Figure 5.6 shows the distribution of impact velocity change observed in the sample of side impact crashes. The modal value was between 36 and 42km/h with a range of impact speeds from 12 to 96km/h. More than 90% of side impact delta-V's were equal to or below 55km/h, while 26% were equal to or below 27km/h (the approximate value for the US design standard for side impacts FMVSS 214, corresponding to a "crabbed" impact velocity of 55km/h and two vehicles of equal mass).

Figure 5.6 Frequency histogram of side impact velocities (delta-V) observed in the sample of side impact crashes inspected to date.



5.5.3 Intrusions and Deformations

Vehicle integrity is likely to be quite different for side impacts than for other crash configurations, given the nature of these collisions. Therefore, it is worth re-examining front and rear seat intrusions for vehicles involved in side impacts separately. Table 5.27 lists the rank ordering of component intrusions into the front and rear seat occupant areas for the sample of side impact crashes, where intrusion is again defined in relation to the space inside the vehicle likely to be occupied by passengers. Most noticeably, front seat intrusions were considerably more common than rear seat intrusions for this population of crashes (2.9 cf. 1.6 intrusions per side crash).

For front seat intrusions, the door panel was the most common area of deformation or intrusion, occurring in 91% of all crashes. B-pillar (41%) and A-pillar (31%) were the next most frequent intruded mechanism, followed by the roof side rail (29%), steering assembly (28%), roof (19%), and side panel (18%). Rear seat intrusions comprised the door panel (64%), roof side rail (21%), roof (19%), B-pillar (18%), and front seat (14%).

Steering assembly intrusions were again quite frequent in these crashes, although not surprisingly more often as lateral (21%) or vertical (18%), rather than longitudinal (3%), movement.

5.5.4 Ejections and Entrapments

The number of occupants ejected or entrapped in their vehicles in side impact crashes is shown in Tables 5.28 and 5.29.

TABLE 5.27
RANK ORDERING OF VEHICLE DAMAGE INTRUSIONS FROM SIDE IMPACTS BY FRONT AND REAR SEATING AREAS (80 vehicles)

FRONT SEAT INTRUSIONS			REAR SEAT INTRUSIONS		
ITEM	FREQ.	(%)	ITEM	FREQ.	(%)
Door panel	73	(91%)	Door panel	51	(64%)
B-pillar	33	(41%)	Roof side rail	17	(21%)
A-pillar	25	(31%)	Roof	15	(19%)
Roof side rail	23	(29%)	B-pillar	14	(18%)
Steering assy	22	(28%)	Front seat	11	(14%)
Roof	15	(19%)	Side panel	8	(10%)
Side panel	14	(18%)	C-pillar	5	(6%)
W'screen/header	7	(9%)	Window frame	1	(1%)
Front seat	5	(6%)	Floor pan	1	(1%)
Instrument panel	4	(5%)	A-pillar	1	(1%)
Console	4	(5%)			
Toe pan	3	(4%)			
Floor pan	2	(3%)			
Window frame	1	(1%)			
Other	2	(3%)			
Totals	**235**			**124**	

STEERING ASSY MOVEMENTS BY DIRECTION OF DISPLACEMENT

Lateral	17	(21%)
Longitudinal	2	(3%)
Vertical	14	(18%)

NB: *Steering assembly intrusions in the top part of the Table 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 in the lower part of the Table.*

There were more non-entrapment cases for non-wearers of seat belts than for belt wearers (80% cf. 61%). However, this needs to be viewed in relation to the small number of non-wearers in the sample (10 cases) and the large percentage of unknowns for these occupants (20%). Additional data is still required to clarify the role between seat belt wearing and entrapment rates in side impact crashes.

Ejection rates in Table 5.29 were as expected. As in frontal crashes, belt wearers appeared again to have had fewer ejections than non-wearers (97% cf. 70%). There was only one recorded cases of an ejection amongst a belt wearers in the sample, compared to the 20% or so of unbelted occupants who were ejected from their vehicle during the collision. Again, this finding needs to be reviewed at a later time when more data are available.

5.5.5 Injury and Source Analysis

As noted earlier, belt wearing was found to have little effect on occupant injuries in this crash configuration and these results are not presented. However, whether the vehicle is impacted on the "near" or "far" side, relative to the injured occupant, is likely to affect the type and severity of injuries and, hence, is of interest here.

The injury and source of injury analysis of side impact crashes by seating position and near and far collision is presented in Tables 5.30 to 5.34. Again, multiple scoring of injuries and points of contact for each patient was allowed, providing they were unique combinations.

TABLE 5.28
ENTRAPMENT ANALYSIS FOR BELTED AND UNBELTED OCCUPANTS INVOLVED IN SIDE IMPACT CRASHES (n=87)

ENTRAPMENTS	BELTED		UNBELTED	
	FREQ.	(%)	FREQ.	(%)
No entrapment	47	(61%)	8	(80%)
Full entrapment	3	(4%)	0	(0%)
Partial entrapment	17	(22%)	0	(0%)
Unknown	10	(13%)	2	(20%)
Total	**77**	**(100%)**	**10**	**(100%)**

TABLE 5.29
EJECTION ANALYSIS FOR BELTED AND UNBELTED OCCUPANTS INVOLVED IN SIDE IMPACT CRASHES (n=87)

EJECTIONS	BELTED		UNBELTED	
	FREQ.	(%)	FREQ.	(%)
No ejection	75	(97%)	7	(70%)
Full ejection	1	(1%)	1	(10%)
Partial ejection	0	(0%)	1	(10%)
Unknown	1	(1%)	1	(10%)
Total	**77**	**(100%)**	**10**	**(100%)**

TABLE 5.30
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 52 DRIVERS IN SIDE IMPACT COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header		2								**2 (0)**
Steering Wheel	2	2	4	4		6	2			**19 (0)**
Steering Column							2			**2 (0)**
Instrument Panel			2 (2)		2 (2)	6	17 (4)	12 (2)		**38 (10)**
Console				2	2		8	4		**15 (0)**
Pillars	4 (4)	2								**6 (4)**
Side Glaze	10 (2)	6				4				**19 (2)**
Door Panel	13 (2)	4	40 (31)	23 (6)	35 (17)	35 (6)	25 (10)	8 (2)	10	**192 (73)**
Roof Surface	6 (6)	4				2			4 (2)	**15 (8)**
Seats	4		2							**6 (0)**
Belts			17 (2)	27	10 (2)	13	2			**69 (4)**
Other Occupant	4 (2)	4 (2)	8 (4)	2		2	2			**21 (8)**
Floor								4 (2)		**4 (2)**
Exterior	12 (4)	8				2		2		**23 (4)**
Non Contact	8	13				6		2	6	**35 (0)**
Other Unknown	13 (2)	12	4 (2)	8	2	21	2	2	8 (2)	**71 (6)**
TOTAL	**75 (21)**	**56 (2)**	**77 (40)**	**65 (6)**	**50 (21)**	**96 (6)**	**60 (13)**	**33 (6)**	**27 (4)**	**538 (119)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved.

DRIVERS - Table 5.30 shows that for all injuries to drivers, the most frequent body regions injured in side impacts were the upper extremities, chest, head, abdomen, and thigh and knee, while for severe injuries (AIS>2), the most frequent body regions injured were the chest, head, pelvis, and the thigh or knee. The most common contact point was the door panel, although the seat belts, instrument panel, and non-contacts were also noteworthy.

The most noteworthy injury/source contacts for drivers in side impact crashes were:

. chest with door panel (40%),
. pelvis with door panel (35%),
. upper extremity with door panel (35%),
. thigh/knee with door panel (25%), and
. chest with seat belt (20%).

For severe injuries (AIS>2) to drivers in side impacts, the most noteworthy injury/source contacts were:

. chest with door panel (31%),
. pelvis with door panel (17%),
. thigh/knee with door panel (10%),
. abdomen with door panel (6%), and
. upper extremity with door panel (6%).

FRONT-LEFT PASSENGERS - Table 5.31 shows the injuries and points of contact inside the vehicle for 27 hospitalised front-left seat passengers involved in side impacts for all and severe injuries only. The most frequent body regions injured for all and severe (AIS>2) injuries included the chest, abdomen, pelvis, head, and the face. Once more, the door panel was, by far, the most common point of contact, along with the seat belts, instrument panel, and exterior objects.

The 5 most noteworthy all injury/source contacts were:

. chest with door panel (63%),
. pelvis with the door panel (44%),
. abdomen with door panel (33%),
. chest with seat belt (30%), and
. abdomen with seat belt (22%).

For severe injuries only to front-left passengers in side impacts, the major injury/source contacts comprised:

. chest with door panel (33%),
. pelvis with door panel (15%),
. abdomen with door panel (15%),
. thigh/knee with door panel (7%), and
. head with exterior object (7%).

REAR SEAT PASSENGERS - Table 5.32 shows the number of injuries (all and severe) and points of contact for the 14 hospitalised rear seat passengers involved in side collisions.

The most frequent body regions injured for these occupants included the upper extremities, chest, abdomen, face, head, and lower leg, while severe (AIS>2) injuries occurred in the chest, abdomen, head, and upper extremities. The two most notable points of contact were exterior objects and the door panel.

The most noteworthy injury/source contacts were:

. chest, abdomen, pelvis, upper ext. with door panel (29%), and
. head, face, chest, abdomen, upper ext., and spine with exterior objects (29%).

TABLE 5.31
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 27 FRONT LEFT SEAT PASSENGERS IN SIDE IMPACT COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	4 (4)	4								**7 (4)**
Steering Wheel										**0 (0)**
Steering Column										**0 (0)**
Instrument Panel		4	4 (4)				15	7		**30 (4)**
Console										**0 (0)**
Pillars	7 (4)	7	4			4				**22 (4)**
Side Glaze	11	7								**19 (0)**
Door Panel		4	63 (33)	33 (15)	44 (15)	19 (4)	15 (7)	19	11 (4)	**207 (78)**
Roof Surface		7								**7 (0)**
Seats								4		**4 (0)**
Belts			30	22	7					**59 (0)**
Other Occupant				4	4 (4)		4			**11 (4)**
Floor										**0 (0)**
Exterior	11 (7)	7	4 (4)	4 (4)		4				**30 (15)**
Non Contact	4	4								**7 (0)**
Other Unknown	15	7	7 (4)					4		**33 (4)**
TOTAL	**52 (15)**	**52 (0)**	**111 (44)**	**63 (19)**	**56 (19)**	**26 (4)**	**33 (7)**	**33 (0)**	**11 (4)**	**437 (111)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved

TABLE 5.32
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 14 REAR SEAT PASSENGERS IN SIDE IMPACT COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header										**0 (0)**
Steering Wheel										**0 (0)**
Steering Column										**0 (0)**
Instrument Panel										**0 (0)**
Console										**0 (0)**
Pillars										**0 (0)**
Side Glaze	14 (7)	14								**29 (7)**
Door Panel		7	29 (29)	29 (14)	29	29 (7)	7	14		**143 (50)**
Roof Surface										**0 (0)**
Seats								7		**7 (0)**
Belts			7		7	7				**21 (0)**
Other Occupant										**0 (0)**
Floor							7	7		**14 (0)**
Exterior	29 (21)	29	29 (21)	29 (21)	7 (7)	29 (7)	21 (7)	21	29	**221 (86)**
Non Contact	7	7								**14 (0)**
Other Unknown						7 (7)				**7 (7)**
TOTAL	**50 (29)**	**57 (0)**	**64 (50)**	**57 (36)**	**43 (7)**	**71 (21)**	**36 (7)**	**50 (0)**	**29 (0)**	**457 (150)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved.

For severe (AIS>2) injuries to rear seat occupants in side impacts, the most noteworthy injury/ source contacts were:

. chest with door panel (29%),
. head with exterior objects (21%),
. chest with exterior object (21%), and
. abdomen with exterior object (21%).

NEAR & FAR COLLISIONS - The final analysis undertaken for side impact collisions was an attempt to examine whether injuries and points of contact were different for occupants seated on the impacted side (NEAR) as opposed to the opposite side (FAR). Previous evidence suggested that there would be differences here (Dalmotas 1983; Otte et al 1984; Rouhana and Foster 1985).

It was only possible to examine near and far differences for drivers, given the small number of cases currently available and the lack of front-left and rear passengers who were hospitalised after far-side impact crashes (4 in 27 and 2 in 10 respectively). Tables 5.33 and 5.34 shows these results.

Near Side Collisions - For the 34 drivers involved in near side impacts (Table 5.33), the most frequent body regions injured were upper extremities, head, chest, thigh and knees, and the abdomen, while for severe (AIS>2) injuries, they were the chest, pelvis, thigh and knees, and the head. The most common point of contact was the door panel, but seat belts and exterior objects were also noteworthy.

The 5 most frequent injury/source contacts for drivers involved in near side impacts were:

. chest with door panel (53%),
. pelvis with door panel (50%),
. upper extremity with door panel (41%),
. thigh/knee with door panel (38%), and
. abdomen with door panel (35%).

For severe (AIS>2) injuries, the most notable injury/source contacts for these occupants included:

. chest with door panel (41%),
. pelvis with door panel (26%), and
. thigh/knee with door panel (15%).

Far Side Collisions - Table 5.34 shows that for the 18 drivers involved in far side impacts, the most frequent injuries were the upper extremity, chest, head, face, and abdomen, while for severe (AIS>2) injuries, they were the chest, head, and pelvis. Points of contact were more varied for these occupant injuries and consisted of the seat belt, door panel, instrument panel, and other occupants.

The most important injury/source contacts for drivers in far side collisions were:

. abdomen with seat belt (44%),
. chest with seat belt (33%),
. upper extremity with seat belt (33%),
. chest with other occupants (27%),
. lower leg with door panel (22%),
. upper extremity with door panel (22%), and
. pelvis with seat belt (22%).

TABLE 5.33
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 34 DRIVERS IN "NEAR" SIDE IMPACT COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header		3								3 (0)
Steering Wheel			6	6		6				18 (0)
Steering Column							3			3 (0)
Instrument Panel						3	18 (3)	6		26 (3)
Console							6	3		9 (0)
Pillars	6 (6)	3								9 (6)
Side Glaze	12	9				6				26 (0)
Door Panel	15		53 (41)	35 (9)	50 (26)	41 (6)	38 (15)	12 (3)	15	259 (100)
Roof Surface										0 (0)
Seats	3		3							6 (0)
Belts			9	18	3	3	3			35 (0)
Other Occupant										0 (0)
Floor								6 (3)		6 (3)
Exterior	18 (6)	12				3		3		35 (6)
Non Contact	9	18				6		3	3	38 (0)
Other Unknown	15 (3)	9	6 (3)	9	3	26	3	3	9 (3)	82 (9)
TOTAL	76 (15)	53 (0)	76 (44)	68 (9)	56 (26)	94 (6)	71 (18)	35 (6)	26 (3)	556 (126)

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved.

TABLE 5.34
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 18 DRIVERS IN "FAR" SIDE IMPACT COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header										**0 (0)**
Steering Wheel	6	6				6	6			**22 (0)**
Steering Column										**0 (0)**
Instrument Panel			6 (6)		6 (6)	11	17 (6)	22 (6)		**61 (22)**
Console				6	6		11	6		**28 (0)**
Pillars										**0 (0)**
Side Glaze	6 (6)									**6 (6)**
Door Panel	11 (6)	11	17 (11)		6	22 (6)				**67 (22)**
Roof Surface	17 (17)	11				6			11 (6)	**44 (22)**
Seats	6									**6 (0)**
Belts			33 (6)	44	22 (6)	33				**133 (11)**
Other Occupant	11 (6)	11 (6)	22 (11)	6		6	6			**61 (22)**
Floor										**0 (0)**
Exterior										**0 (0)**
Non Contact	6	6				6			11	**28 (0)**
Other Unknown	11	17		6		11			6	**50 (0)**
TOTAL	**72 (33)**	**61 (6)**	**78 (33)**	**61 (0)**	**39 (11)**	**100 (6)**	**39 (6)**	**28 (6)**	**28 (6)**	**506 (106)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries. figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved

For severe (AIS>2) injuries, the most frequent injury/source contacts for far impacted side drivers were:

. head with roof (17%),

. chest with door panel (11%), and

. chest with other occupant (11%).

5.5.6 Bull Bars in Side Impacts

Of the 80 side impact cases so far inspected, 13 patients (16%) were hospitalised from contact with a vehicle likely to have a bull bar fitted (such as a 4WD, forward control van, or a truck). In **four** of these cases, a bull bar was clearly identified from material collected (there was no allowance for coding bull bars on the NASS format). In these cases, occupant injuries could be attributed to contact with the bull bar, either directly or through the intruding vehicle surface such as a door or window. Two of the four patients subsequently died from injuries resulting from direct contact with the bull bar.

5.5.7 Side Impact Summary

The side impact findings are only preliminary at this time because of the small amount of data currently available. Care should be taken in interpreting these results.

Three-quarters of all side impacts involved passenger compartment intrusions. Roughly half of them were perpendicular and half oblique impact directions. Impact velocity change was generally lower for side than for frontal impacts. Twenty-six percent of these delta-V's were equal to or below 27km/h.

There were roughly twice as many intrusions in the front passenger compartment as the rear. Door panels, pillars, roof side rails, and the roof itself were frequent intruding structures in these impacts.

Six out of ten belted and eight out of ten unbelted occupants experienced no occupant entrapments in side collisions. There were practically no cases of occupant ejections amongst belt wearers yet roughly 20 percent amongst non-wearers. Some of these differences may be, in part, a function of the small amount of data available at this time.

Occupants of vehicles involved in side impacts sustained a high proportion of severe injuries to the chest, head, pelvis, thighs and knees, and the abdomen from contacts mainly with the door panel. There was no sign that the steering assembly was especially hazardous to drivers in these impacts.

"Near" side impacts were over-involved in these cases, although a sizable number of drivers did sustain hospitalised injuries from "far" side impacts (especially involving contacts with the seat belt and instrument panel). While "near" side impact contacts closely mirrored the overall side impact findings, "far" side contacts were noticeably different in that the seat belt and other occupants gained in importance in their injurious effects.

Drivers tended to experience more body regions injured from side impacts than did those in all other seating positions. It is somewhat surprising that while head injuries ranked highly as a body region injured in these crash configurations, it did not rank highly in the injury/source contact analysis for any of the three seating positions. This may have been, in part, a function of the relatively large number of head injuries where a point of contact could not be identified.

5.6 VEHICLE ROLLOVERS

Collisions involving vehicle rollover are not particular frequent types of road crashes (10% of hospitalised TAC claims and 5% of patients in the crashed vehicle study). However, they do tend to result in very severe and disabilitating injury to the occupants involved in these collisions, and injury interventions are likely to be different for rollovers, compared to other crash types.

As the number of vehicles and patients studied in this category were small (11 and 12 cases respectively), this final analysis, too, is only preliminary at this stage and will be reported upon in much more detail at a later time when more data have been collected.

5.6.1 Rollover configurations

Figure 5.7 shows the various types or extents of rollovers observed in the crashed vehicle sample to date. Of the cases where rollover extent could be assigned, most were full turns or more or end-to-end, compared to only partial rollovers.

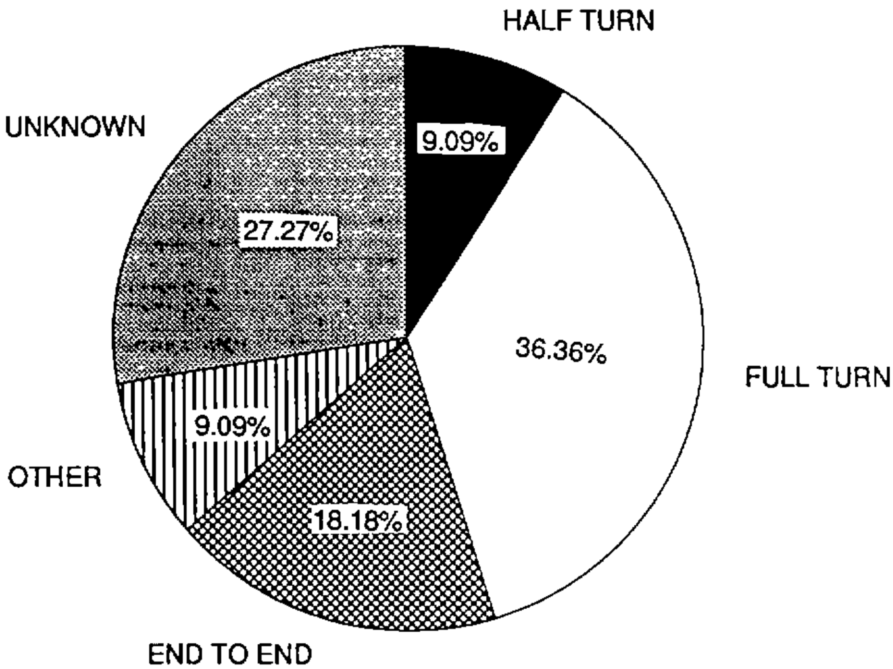


Figure 5.7 *Extent of vehicle rollover observed in the crashed vehicle sample at this time.*

TABLE 5.35
RANK ORDERING OF VEHICLE DAMAGE INTRUSIONS FOR ROLLOVERS BY FRONT AND REAR SEATING AREAS (11 vehicles)

FRONT SEAT INTRUSIONS			REAR SEAT INTRUSIONS		
ITEM	FREQ.	(%)	ITEM	FREQ.	(%)
Roof	14	(127%)	Roof	12	(109%)
Roof side rail	6	(55%)	Roof side rail	3	(27%)
A-pillar	5	(46%)	C-pillar	2	(18%)
W'screen/header	4	(36%)	B-pillar	1	(9%)
B-pillar	3	(27%)	Side panel	1	(9%)
Steering assy	1	(9%)			
Totals	**33**			**19**	

5.6.2 Intrusions and Deformations

Table 5.35 lists the rank ordering of component intrusions into the front and rear seat occupant areas for the sample of rollover collisions (intrusion is once more defined in relation to the space inside the vehicle likely to be occupied by passengers). As previously recorded for other crash types, there were more intrusions in the front than the rear seat passenger compartment (3.0 cf. 1.7 per crash). By far, the most common intrusions observed in these crashes were from the vehicle roof and roof structure. In addition, there were a sizable number of intrusions also from the roof supports (the A-, B-, and C-pillars).

5.6.3 Ejections and Entrapments

The number of occupants who were ejected or entrapped in their vehicles in rollovers is shown in Tables 5.36 and 5.37. Because of the very small numbers of cases in each category, it is impossible to make anything of these results at this time.

TABLE 5.37
EJECTION ANALYSIS FOR BELTED AND UNBELTED OCCUPANTS INVOLVED IN ROLLOVER CRASHES (n=9)

EJECTIONS	BELTED		UNBELTED	
	FREQ.	(%)	FREQ.	(%)
No ejection	5	(84%)	2	(67%)
Full ejection	0	(0%)	1	(33%)
Partial ejection	0	(0%)	0	(0%)
Unknown	1	(16%)	0	(0%)
Total	**6**	**(100%)**	**3**	**(100%)**

TABLE 5.36
ENTRAPMENT ANALYSIS FOR BELTED AND UNBELTED OCCUPANTS INVOLVED IN ROLLOVER CRASHES (n=9)

ENTRAPMENTS	BELTED		UNBELTED	
	FREQ.	(%)	FREQ.	(%)
No entrapment	4	(67%)	3	(100%)
Full entrapment	0	(0%)	0	(0%)
Partial entrapment	1	(17%)	0	(0%)
Unknown	1	(17%)	0	(0%)
Total	**6**	**(100%)**	**3**	**(100%)**

5.6.4 Injury and Source Analysis

Table 5.38 shows the injury/source contacts for the 12 occupants hospitalised from rollover collisions in this study.

In order of frequency, the body regions injured included the upper extremity, head, face, spine, and chest, while for severe (AIS>2) injuries, they were the head, chest, and the spine. The main points of contact for occupants in rollovers were the roof, exterior objects, the door panels, and side glazing. There was a sizable number of injuries for which a point of contact could not be identified in these crashes.

The most noteworthy injury/source contacts for all occupants in rollover crashes were:

. head with roof surface (42%),

. upper extremity with door panel (42%),

. face with side glazing (33%), and

. head with side glazing (25%).

For severe (AIS>2) injuries, the most frequent injury/source contacts were:

. head with roof surface (17%), and

. head with side glazing (17%).

5.6.5 Rollover Summary

The results of the rollover analysis are very restricted because of the very few cases involved at this time. Like the side impact analysis, care needs to be taken in inferring very much from these preliminary findings. Full turn and end-to-end were more common than partial turn roll-over configurations amongst the sample. It was not possible to measure impact velocity for these crashes using CRASH 3.

There were more intrusions in the front than the rear passenger compartment. The roof and its structural members were the major source of intruding mechanisms in these vehicles. There were too few cases to infer anything meaningful from the entrapment and ejection analyses.

The head, chest, and spine featured amongst the severe injuries incurred by these occupants. Contacts with the roof, door panel, side glazing and the exterior were most common in rollover collisions. It should be noted that the source of injury for a sizable proportion of body region injuries (including both all and severe injuries) could not identified in these crashes.

5.7 BENEFITS & SHORTCOMINGS WITH THESE DATA

The greatest benefit from the crashed vehicle study data is in the ability to relate occupant injuries with the specific vehicle component considered to be the source of injury. As noted earlier, this type of data is not normally available from mass data analysis, usually requiring a case by case in-depth analysis. Thus, the injury/source analysis conducted here is a unique opportunity to identify areas of vehicle design and construction which show potential for improvement to reduce occupant injuries in current model vehicles.

The after-the-event style of crash inspection adopted here proved to be a reliable method for collecting this type of information. It is recognised that this approach is not suited to ascribing causes and culpability to vehicle crashes. Nevertheless, it is a tried and proven means of collecting occupant safety information which costs only about one third of the cost of at-scene investigations.

The greatest shortcoming with these data relates to the relatively small numbers involved to date. The results reported here are based on an analysis of 227 crashed vehicles and 269 injured occupants. Some of the findings reported in this section were based on very few cases (e.g., for non-belt wearers in rollover collisions). Except for front seat occupants in frontal crashes, therefore, it is difficult to be sure how robust many of these findings are without additional data.

Furthermore, detailed statistical analysis of apparent differences were not systematically performed on these mean values for two reasons. First, the insufficient numbers in many of the cells invalidated the assumptions of the most reliable standard tests of significance of these data (e.g.,

TABLE 5.38
RATE OF BODY REGION INJURIES BY SOURCE OF INJURY FOR ALL INJURIES & SEVERE (AIS>2) INJURIES ONLY FOR 12 OCCUPANTS INVOLVED IN ROLLOVER COLLISIONS.

	Head	Face	Chest	Abdomen	Pelvis	Upper Limb	Thigh & Knee	Lower Leg	Spine	TOTAL
Windscreen & Header	8					17				**25 (0)**
Steering Wheel				8						**8 (0)**
Steering Column										**0 (0)**
Instrument Panel										**0 (0)**
Console										**0 (0)**
Pillars										**0 (0)**
Side Glaze	25 (17)	33								**58 (17)**
Door Panel						42		8	8	**58 (0)**
Roof Surface	42 (17)	17							17	**75 (17)**
Seats										**0 (0)**
Belts			17	8		8			17	**50 (0)**
Other Occupant										**0 (0)**
Floor										**0 (0)**
Exterior	17 (8)	8	8 (8)	8 (8)		17			8	**67 (25)**
Non Contact		8				8	8		8 (8)	**33 (8)**
Other Unknown	25 (8)	8	17 (17)	8	8	42				**108 (25)**
TOTAL	**117 (50)**	**75 (0)**	**42 (25)**	**33 (8)**	**8 (0)**	**133 (0)**	**8 (0)**	**8 (0)**	**58 (8)**	**483 (92)**

TOP row figures show the injury/source contact rates per 100 patients for all injuries; figures in PARENTHESIS are the contact rates per 100 patients for severe injuries only (AIS>2). Multiple injuries are included where separate injury sources were involved.

Chi-square). Second, conducting tests of significance on such small numbers can be subject to errors of interpretation (especially Type 2 error, leading to a false rejection of an apparent difference). There is clearly a case for continuation of the crashed vehicle study component so that sufficient data are available to confirm or reject many of the preliminary findings reported here and to enable time trends to be performed on data collected over several years.

Finally, it is almost impossible to derive involvement rates for many of the findings reported here without reliable exposure data. Recall that the findings relate to a hospital patient database only (inclusion in the study required admission to one of the study hospitals). Accurate exposure information on vehicle populations, age and seating position, sex, vehicle speeds, etc is not readily available for Victoria.

Moreover, information could not always be collected on other occupants involved in the collision and deaths that occurred prior to arrival at hospital. Hence, it is impossible to compare accurately the performance of particular vehicles in relation to those killed, injured, and uninjured without this additional information.

6. DISCUSSION OF THE CRASHED VEHICLE RESULTS

There were several important findings in the crashed vehicle study that need to be elaborated upon in respect of the types of injuries and sources of these injuries for occupants of current generation passenger cars. They will be discussed in terms of the collision types and occupant seating positions experienced in order of frequency of occurrence in the vehicles investigated.

This discussion will concentrate on common injuries and points of contact within the vehicle that occupants of current generation passenger cars are experiencing in modern day vehicle crashes. Chapter 7 will try to bring this information (along with that emanating from the mass data analysis) into a coherent account of current occupant protection issues that still require resolution.

6.1 REPRESENTATIVENESS OF THE SAMPLE

To date, 227 vehicles containing 269 occupants have been fully inspected and entered into the crashed vehicle database. A decision was made recently to expand the number of vehicles to provide a more definitive database. However, it is worth reviewing how representative the current database is in the light of the discussion to follow. It should be remembered that entry into this sample required the hospitalisation of at least one of the occupants of a passenger car (or derivative) first registered in 1982 or later that was involved in a road crash in the Melbourne Metropolitan area or within approximately 1 hour's drive of Monash University (69% metropolitan and 31% rural crashes).

The types of crashes in the sample involved 60% frontals (pure front or offset), 35% side impacts and 5% rollovers; there were no rear end crashes included in the study. Comparing these figures with the hospitalised patients in the mass data supplied by the Transport Accident Commission shows roughly the same proportions for front impacts (60% cf. 65%) but more than twice the proportion for side impacts (35% cf. 14%). In addition, there were no rear-end hospitalised patients reported in this study compared to 11% listed in the TAC hospitalised data and the proportion of rollovers was also less in these data (5% cf. 10%). This indicates differences in the methods of coding impact direction between the two data sets.

It is also possible that there may be a small bias in the types of patients observed in this study (multiple crashes were excluded and the four study hospitals may tend to admit the more serious or life threatening cases). However, given the detailed nature of the inspection process used here, it is likely that the number of side impacts is under-reported in the mass data. Indeed, Heulke, Compton and Studer (1985) reported that the percentage of side impacts in the NASS system in the U.S.A. was 28%, derived from data collected using a similar in-depth approach.

The patient characteristics show that there were roughly equal numbers of male and female patients in the sample as there are approximately in the general population (ie, neither sex appeared to be over-represented here), although there were 4% fewer females in this sample than that observed in the TAC data. Young adults (those aged 17 to 25 years) were over-represented as patients compared with their population statistics (27% cf. 15%) which was expected from previous reports of the over-involvement of these people in road crashes (Drummond 1989). The very old (those aged over 75 years) were slightly under-represented as patients, compared with population statistics (3% cf. 4%). While it is expected that the old and frail would be more likely to be hospitalised from vehicle crashes, this is obviously offset by their lack of exposure as vehicle occupants.

The sample of crashed vehicles comprised 5% mini-cars, 25% small cars, 40% compacts, 28% intermediates, and 2% large cars. The majority of these vehicles had automatic transmissions and were rear-wheel drive, although 43% of them did have front-wheel drive configuration. There was a preponderance of popular makes and models in the sample. Because of a lack of availability of accurate make and model information of the current vehicle fleet in Victoria at this time, it is impossible to know how representative the sample of crashed vehicles was.

6.1.1 Conclusion

These findings reveal that the crashed vehicle sample was generally representative of the population of vehicle occupants although biased towards the more serious types of crashes. As this only acts to emphasise the types of injuries and sources of injury of those hospitalised from road crashes in current generation vehicles, this bias is not of any major concern here. It is not possible to say anything definitive about the relative involvement rates of the different types of vehicles without further exposure data. However, the vehicle sample does not appear to be markedly different to that generally known about vehicles on the road. In short, these data appear to be quite suitable for conducting an analysis of occupant injuries and vehicle contacts from modern day passenger car crashes.

6.2 OVERVIEW OF INJURIES & CRASHES

The analysis covering all collisions enables an overview of the types of injuries sustained and the sources of injury for the total crashed vehicle sample. Caution should be taken in assuming this is representative of the incidence of injury and vehicle contacts for the reasons outlined earlier in terms of sample bias. Nevertheless, it is at least indicative of the relative frequencies of vehicle occupant injuries and vehicle contacts for those hospitalised from road crashes. More importance will be placed on the analysis by crash type in attempting to identify countermeasures against these injuries, although this first report will only address frontal crashes.

6.2.1 Body Regions Injured

Across all the different crash configurations inspected in this study, there was a tendency for drivers to have more body region injuries than other seating positions. In addition, drivers tended to sustain more severe injuries than other occupants (AIS>2 and ISS>15), although front-left passengers experienced the most severe injuries of all (ISS>25). There did not appear to be any particular seating position bias in the average number of severe injuries per patient. It should be stressed that these findings might be influenced somewhat by the fact that occupants had to be hospitalised to be included in the study where a severe injury was probably a pre-requisite.

The types of injuries sustained, though, were different across the three seating positions. There was a higher likelihood of a head, lower leg, and pelvis injury for front seat passengers, and a spinal injury for for rear passengers, although the latter were more likely to sustain a severe head injury (AIS>2). All positions seemed equally vulnerable to injuries (major and severe) to the face, chest and abdomen. Upper and lower extremity injuries were somewhat more prevalent among drivers than other occupants, probably resulting from the steering assembly and foot pedals. Rear seat passengers experienced a greater percentage of a spinal injuries than front seat passengers, although front-left seat passengers sustained the highest proportion of **severe** spinal injuries. It was not possible to directly compare the number of body regions injured and the average numbers of injuries sustained by these patients with the mass data analysis because of major differences in coding procedures in these data.

6.2.2 Points of Contact

The most common vehicle components associated with injuries to front seat occupants in all crash configurations included seat belts, door panels, the steering wheel (for drivers), instrument panels, and windscreens and headers. In terms of severe injury contacts to those seated in the front, door panels and rails, the steering wheel, and the instrument panel were particularly involved. For rear seat passengers, door panels, too, and seats and seat belts seemed to be the most common areas contacted, with door panels over-involved in severe injuries to these occupants.

6.2.3 Conclusion

It is difficult to say anything too definitive about these findings, given the variety of different crash configurations involved in producing these injuries (it is more meaningful to examine these findings further by crash type). However, this overview does suggest that injuries to head and upper torso are of such frequency in modern crashes to be of major concern. Moreover, contacts with seat belts, roofs, doors, steering assemblies, and instrument panels are still common sources of these injuries. The exact relationships between injuries and source of injury will be examined further in the following sections, by each of the different crash configurations.

6.3 FRONTAL CRASHES

The overwhelming abundance of frontal collisions in vehicle crashes on the road demands that they receive primary focus in improving vehicle occupant protection. Moreover, given the predominance of vehicles containing a driver and and/or front passenger, these occupants also deserve special attention.

6.3.1 Characteristics

The frontal impact analysis revealed slightly higher impact velocity changes (delta-V) than were reported for all collisions. Roughly half these frontal crashes which resulted in at least one occupant being hospitalised had impact velocity change equal to, or less than, that specified for frontal barrier tests (48km/h). That is, a sizable proportion of these occupants were hospitalised from crashes for which they should have been adequately protected. This alone demonstrates there is considerable scope (and need) for further improvements in occupant protection in current generation passenger cars in this country.

The breakdown of the different types of frontal impacts was interesting, showing roughly equal proportions of crashes as pure frontals, offset frontals, and oblique frontals. This suggests the need to consider different configurations when specifying frontal crash performance (a debate which is currently gaining momentum in respect to front barrier test performance overseas).

6.3.2 Body Region Injuries

In frontal impacts, both drivers and front seat passengers appeared to sustain more injuries (including severe AIS>2 injuries) than rear seat passengers. Drivers sustained a sizable number of severe injuries to their chest, thigh/knee, lower leg, and their head. Front-left passengers also sustained a noteworthy number of severe injuries to their chest, upper extremities, and thigh/knees, as well as a sizable number of spinal injuries from frontal crashes. Most of these front seat occupants were wearing seat belts at the time of their collision. There were some differences in the pattern of results for unrestrained occupants in that they had more head, face, and upper extremity injuries from different contacts within the vehicle. There was a hint that belted front seat occupants alone sustained slightly more chest and abdomen injuries (although not necessarily severe injuries) from contacts with the seat belt and steering wheel.

These results are quite similar to those reported by Jones (1982) for belt wearers except for the high incidence of abdominal injuries to drivers observed in this study. The reasons for this difference are not clear and may be a function of slight differences in coding injuries between the two studies (there was a higher percentage of lower extremity injuries in Jones 1982 than observed here which might suggest that he coded some of our abdominal injuries as lower extremity injuries).

The results here, however, differ from those reported by Backaitis and Dalmotas (1985) for belted drivers in respect of the overwhelming number of severe head injuries they reported (head injuries in their study was the principal severe AIS>2 injury observed for belted drivers, compared with the 5th most important injury here). As their belted data was collected during the 1970s, it may be that there were marked differences in the types of 3-point restraints evaluated in these two studies.

Rear seat occupants sustained a number of severe injuries to the head, abdomen, and upper extremity. Because of the limited amount of data available in this seating position, it was not possible at this time to examine whether there were differences in injuries between belt wearers and non-wearers.

6.3.3 Points Of Contact

In frontal crashes only, the steering wheel, instrument panel, seat belts, and the floor were the outstanding sources of injury (for both all and severe injuries) to drivers, while the instrument panel and seat belts were the major source of total and severe injury to front-left seat passengers. Rear seat occupant injuries resulted from contacts with the seat belt, front seats, rear window, and the doors (this latter source being the major contact for severe rear seat occupant injuries.

Comparing these results with other published findings for belted drivers and front seat passengers was illuminating. There was considerable agreement with the rank ordering of points of contact for severe injuries to belted drivers in this study with those reported by Jones (1982), Backaitis and Dalmotas (1985) and Appel and Wustemann (1986) if the contacts for the wheel and belts are summed (i.e., there appear to be differences in attributing a particular injury as contact with either the belt or the wheel across these studies). For front seat passengers, however, the three other studies reported considerably more belt contacts than was observed here. As a belt contact in this seating position is less ambiguous than for the driver (there is no steering wheel to conflict with this judgement), this result again hints at the fact that belts in current generation passenger cars in Australia may be out-performing those examined in other (older) studies overseas.

The rear seat contacts were somewhat similar to those reported by Bodiwala, Thomas and Otubushin (1989) who found that most injuries to approximately 670 unrestrained rear seat occupants were the result of contact with the front seat, glazing materials, or with other parts of the car. Differences in the results between these two studies can be almost totally explained by differences in rear seat belt wearing behaviour.

6.3.4 Injuries And Contacts

The results of the injury/source analysis of those involved in frontal impacts were interesting. Front seat occupants (drivers and passengers) sustained considerable injuries (including both minor and severe injury) to their heads, chests, abdomens, upper and lower extremities from contacts with the steering wheel, seat belts, instrument panels, and windscreens. This was in spite of the fact that the vast majority of them (82-84%) wore retractable 3-point seat belt restraints.

Apart from contacts with the belt itself, differences in components contacted for non-wearers of seat belts included an increased number of windscreen/header, and external object contacts. For belted front seat occupants in frontal crashes, contacts between the chest, abdomen, and pelvis with the steering wheel (drivers), instrument panel and seat belts were particularly common amongst this group of restrained occupants. While head contacts with the steering wheel and windscreen did not always rank high in terms of frequency of occurrence, there were, nevertheless, sufficient instances observed (given their high life threatening nature) to be of some concern to front seat occupants in these data.

Rear seat passengers tended to sustain relatively fewer (and different) injuries than did front seat occupants. In particular, they received fewer head and chest injuries, although proportionally more spine and upper extremity injuries, and the points of contact were more likely to be roofs, doors, the back of the front seats, and the rear windscreen and header. It was not possible to assess whether seat belt wearing in the rear seat markedly influenced this pattern of results because of the small amount of data available at this time.

Front-left passengers had proportionally more contacts with the instrument and door panels, while drivers had more steering wheel contacts. While these differences might suggest some benefit in reduced injury contacts with these panels from the steering wheel assembly holding the occupant more in place, this is more than offset by the increased percentage of injuries (both minor and severe) from driver contacts with the steering wheel itself.

There were fewer contacts overall for rear seat occupants, although their high percentage of contacts with the front seat should be noted (95%). As 11% of these contacts involved severe injuries (with 5% of the vehicles experiencing a front seat distortion or intrusion), this is a little disturbing, given the likelihood that some of the injuries to front seat occupants may well have been exacerbated by these rear seat contacts (Lowenhielm and Krantz 1984; Mackay 1990).

6.3.5 Frontal Impact Integrity

In frontal crashes, there were considerable intrusions into the front passenger cabin, even though half the number of crashes were at impact velocities below that specified in barrier testing. These intrusions included movement of the toe pan and front floor, instrument panels, steering assemblies, side panels, and console, although there were also a sizable number of major structural intrusions and deformations observed to the roof, and pillars. Longitudinal steering column movements generally performed up to ADR 10/01 requirements, although there were a sizable number of upward and sideways movements of the column, not presently covered by this ADR.

The drive configuration intrusion analysis was a new finding. There appeared to be considerably more intrusions of the toe pan, instrument panel, and steering assembly for rear-wheel than front-wheel drive compact vehicles. Moreover, longitudinal steering movements were more common amongst RWD than FWD configurations. This was not a function of different impact velocities because they essentially had similar distributions.

While the numbers are really too small yet to form definitive conclusions from these findings, it seems to suggest that the different steering assembly layout for FWD compact vehicles may be safer for front seat occupants in head on crashes than similar RWD vehicles, and hints of improved protection for these occupants in minimising intrusions possibly from lateral engine and transmission layouts or stronger support members.

This deserves further investigation for other vehicle sizes (if possible) when there are more data available.

6.3.6 Entrapment and Ejection

The influence of seat belt wearing on entrapment and ejection rates in frontal crashes was as expected. Seat belt wearing did not influence entrapment rates while offering a perfect performance on preventing occupant ejections in these crashes. These results confirm the desirability of the 3-point retractable seat belts used in this country as a primary restraint mechanism. The incidences of vehicle ejections reported overseas (eg, 18% in the U.S.A. for a 2-point motorised system; Evans, 1990) confirmed the efficacy of the Australian restraint system in preventing ejections.

This is not to say that there are not problems with present day Australian seat belts as the injury and contact analysis showed, but rather, that the basic system in this country is a superior form of occupant belt restraint than alternative (passive) systems.

6.3.7 Conclusion

Drivers in current generation passenger cars in Australia who are hospitalised from road crashes are experiencing considerable injury to the face, chest, and to a lesser extent the head, from contact with the steering wheel. This was observed for all and frontal crash configurations for seat belt wearers and non-wearers. In addition, front seat occupants sustained a sizable number of head, face, chest, and abdomen injuries from the seat belt, instrument panel and windscreen and header in frontal crashes (the most common form of collision on the road). Lower extremity injuries to the thighs, knees, and lower legs from the instrument panel were also quite common. Rear seat occupants experienced fewer upper torso and head and face injuries but substantially more spinal injuries.

A considerable number of these occupants were hospitalised from relatively low speed crashes which should be less injurious. These observations indicate there is considerable scope for further reducing vehicle contacts for all occupants involved in frontal collisions.

6.4 SIDE IMPACT COLLISIONS

The differences in the proportions of side impact collisions between these data and those supplied by the TAC were noted earlier, suggesting differences in the coding methods used in both these data sets. It was argued that the method used in this study was likely to be the more accurate for occupant protection analysis, given the detailed inspection process.

There was a higher tendency for long-term hospitalisation from side impacts compared to all other types of crashes in the TAC data. This typifies the relative seriousness of this type of crash for occupants of all vehicles in Australia and the need for improved occupant protection against side impact collisions. Unfortunately, though, there were only relatively small numbers of these cases inspected so far, and care should be exercised in using these results. A subsequent report is planned at a later time, concentrating on side impacts and other configurations, when more data is available.

6.4.1 Characteristics

The sample of 80 side impact crashes investigated to date revealed that three-quarters of them incurred impact damage to some part of the passenger compartment. Moreover, half of these impacts were perpendicular while the other half, oblique. This suggests that any side impact test arrangement should really take account of all these impact conditions.

Impact velocities for side impacts, where at least one occupant was hospitalised, were much lower than for frontal crashes, confirming the more dangerous nature of these crashes. The recently introduced US requirement for side impact testing (FMVSS 214) specifies a 30mph (48km/h) "crabbed" impact velocity of the bullet vehicle. For vehicles of equal mass, this equates to a 27km/h perpendicular impact velocity of the struck vehicle. At this value, one-quarter of the vehicle occupants observed in this study were injured sufficiently to require hospitalisation. Clearly, there is also an urgent need for further improvements in occupant protection from side impact crashes in current model vehicles.

6.4.2 Body Region Injuries

For the side impact crashes inspected in this study, there was a tendency for drivers to have more body region injuries than front-left or rear passengers. However, those in the rear had more severe injuries than did front seat occupants. It should be stressed again that these findings might be influenced somewhat by the few cases involved and by the fact that occupants had to be hospitalised to be included in the study.

A higher proportion of drivers were hospitalised from "far" side impacts than other seating positions. This was in spite of the fact that contacts with the steering assembly were minimal for this crash configuration. This suggest a difference in exposure for left and right side crashes and needs further investigation.

The types of injuries sustained differed across the three seating positions. There was a higher likelihood of a head, chest, upper and lower limb injury (all and severe injuries) for drivers than for front or rear seat passengers, although front-left passengers experienced more chest injuries. These differences may be in part a function of the disproportionate number of far-side drivers injured in this sample. Abdominal and pelvic injuries were more apparent for front seat than rear seat occupants, while rear passengers were more at risk of a severe head injury. This may reflect differences in the area of the vehicle impacted and/or differences in belt wearing rates between the front and rear seating positions.

For those drivers involved in both "near" and "far" side collisions, there were quite similar proportions of total body regions injured (except for more thigh/knee injuries from near side crashes). There was, however, a greater proportion of severe chest and pelvis, with fewer severe head injuries, from far side impacts. The sources of these injuries inside the vehicle, though, were quite different for the different sides impacted.

Severe lower extremity injuries were more prevalent amongst drivers suggesting that these occupants may have a particular problem with the floor pans and foot pedals. Front-left passengers had far fewer minor spinal injuries than either rear seat passengers or drivers in these crashes. It is not clear at this stage if this is a real difference or simply a function of the small sample size.

The injury findings were quite similar to those observed in the mass data. Other researchers, too, have reported similar findings of severe injuries to the chest, abdomen, and head/neck regions of the body by driver and front passenger, in U.S.A. (Rouhana and Foster, 1985), and the U.K. (Jones 1982), or for front passengers combined (Otte et al, 1984). Dalmotas (1983) found that head and face injuries were marginally more common than chest and abdomen/pelvis injuries for his sample of 98 side impact crashes in Canada during the 1970's. While there may be slight differences in the order of body region involvement across these studies, clearly these body regions are most at risk of severe injuries from side impact crashes.

Interestingly, there were very few differences in order or proportions of body regions injured by whether the driver was positioned on the near- or far-side of the impacted vehicle, either here or in all of the other studies noted above. The greatest effect on occupant injuries from the near and far relationship in side impact collisions appears to be in which vehicle component actually caused the injury. This will be discussed more fully in the next section.

There was a slight difference in the percentage of severe seat belt injuries between drivers and front-left passengers (4% cf. 0%). This is a little surprising as they had similar seat belt wearing rates overall. In addition, the analysis for frontal crashes shows a reversed trend (12% cf. 18%), in seat belt contacts for belted occupants in these two seating positions, suggesting that this anomaly may be a function of differences in the proportions of near and far impacts across these two front seating positions. It might also be related to age and sex differences between occupants in these two seating positions or there may have been minor differences in the coding of belt contacts when the steering wheel was present (some of the seat belt contacts for drivers may have actually been the result of contact with the steering wheel). Further analysis is warranted when there are more cases available.

6.4.3 Points Of Contact

The most common vehicle components associated with injuries to front seat occupants in side impacts were the door panel, seat belts, and instrument panel, for all and severe injuries. In rear seating positions, the door panel was also a major source of injury to these occupants but second to contacts with exterior objects. All body regions seemed to come into contact with exterior objects in the back seat, suggesting that ejections and massive intrusions may be a particular problem in this seating position. This deserves closer attention.

As noted above, the points of contact for the drivers' injuries varied, depending upon whether they were seated on the near or far side of the impacted vehicle. In near side impacts, the door panel was the major source of injury for drivers. In far side impacts, however, injuries were caused by a greater range of components inside the vehicle, namely seat belts, instrument panels and consoles, other occupants, door panels and the roof. Surprisingly, seat belts were involved in 11% of severe injuries to these occupants. The steering assembly accounted for very few contacts to drivers in side impact collisions.

The results are remarkably similar to those reported for drivers by Jones (1982), Dalmotas (1983), and Rouhana and Foster (1985). They found interior surfaces to be the common cause of severe injuries to both drivers and front seat passengers when involved in near-side crashes, which was not appreciably influenced by whether the occupant was restrained or not. Most of these authors also reported a greater involvement in occupant injuries from the steering system, instrument panel, and glovebox and a lesser involvement in seat belt injuries than was observed here. This was most likely a function of the low belt wearing rates in this earlier study, compared to that experienced here. Otte et al (1984), too, reported over-involvement of the door and its hardware in front seat occupant injuries in near-side impacts and a sizable number of seat belt injuries to the abdomen for those who were wearing belts. Unfortunately, though, they did not differentiate between driver and front seat passenger contacts.

6.4.4 Injuries And Contacts

The results of the injury/source contact analysis of those involved in side impacts casts some further light on the relationship between occupant injuries and the points of contact inside the vehicle. For drivers and front-left passengers in near-side impacts, door panels were associated with injuries to the abdomen, chest and upper extremity in that order. This demonstrates the need to emphasise occupant protection in the lower door region, rather than in the upper structures of the side of the vehicle. For drivers in far-side crashes, there was an abnormally high rate of seat belt injuries to the chest, abdomen, pelvis, and upper extremity of the body. This suggests the need for better lateral support in seat design (and maybe further improvements in seat belt geometry) to protect these occupants.

For rear seat passengers, chest, abdomen, pelvis, and upper limbs again featured quite highly in contacts with interior door surfaces, showing that there is a need for improved strengthening and better internal padding of both front and rear doors and supporting structures. The rate of injuries from exterior objects for practically all body regions is of some concern for these rear seat occupants and suggests more attention needs to be paid to vehicle structure in the rear and higher restraint wearing.

6.4.5 Side Impact Integrity

Intrusions and deformations from side impacts were noticeably different than for frontal crashes. There was a marked increase in the number and rate of door, pillar, side rail and roof intrusions, as well as an increase in steering column movements. Moreover, there were many more injury/source contacts observed in these crashes from intruding components than for head on crashes. This was in spite of the fact that impact velocities were markedly less for side impacts. Clearly, there is a case for greater attention to structural improvements in the side of the vehicle to optimise occupant protection.

6.4.6 Entrapment and Ejection

Once again, there was clear evidence of the effective performance of seat belts in preventing ejections from side impacts from these data. While the restraint system is primarily aimed at frontal occupant protection, it is still beneficial in side crashes in keeping the occupant inside the vehicle. The small hint of a slight disbenefit from seat belts in vehicle entrapments is probably a function of the small number of cases observed in the sample so far.

6.4.7 Bull Bars

Involvement of bull bars on the striking vehicle appeared to be excessively high for the small number of cases so far investigated. While the numbers are too small yet to draw any definitive conclusions, there was a high fatality and severe injury rate amongst the occupants involved which could be attributed to contact with the bull bar. On four-wheel-drive vehicles and passenger vans, the top rail of these units is often located at head height. Indeed, for the fatal outcomes examined in this study where a bull bar was known to be fitted, the coroner's assessment of the cause of death from injury was directly attributed to contact with the bull bar. Given the seriousness of this finding, there is clearly a case for a detailed examination of the injurious effects of these units on vehicle occupants involved in side impacts.

6.4.8 Conclusion

In summary, occupants of vehicles involved in side impacts sustained a high proportion of injuries to the head, upper torso from contacts with door panels, rails, and for rear seat passengers, exterior objects. Drivers seemed to be especially at risk of being injured from "far" side impacts but this may be a function of the frequency of left-side impacts. The seat belt was implicated in a surprising number of injuries in side impacts suggesting that design improvements to the belt arrangements and seat (a more "winged" design) are needed. Head injuries ranked reasonably highly as a severe injury to these occupants, confirming the need for greater attention in reducing these contacts in future safety designs.

Side impact configurations predominantly involved impact with the passenger compartment, either perpendicular to or at oblique angles. Impact velocities were lower overall, confirming the dangerous nature of the crashes, and one in four crashes occurred with an impact velocity change below that specified in FMVSS 214.

While there is clearly a need for more data to be collected to firmly establish the patterns observed here, the trends so far indicate there is considerable scope for further reducing vehicle contacts and resulting injuries for all occupants involved in side impact collisions.

6.5 VEHICLE ROLLOVERS

Rollover of the vehicle was involved in 5% of the crashes inspected in the crashed vehicle study. While this is a relatively small proportion for this crash configuration, nevertheless, it is a potentially severe type of crash in terms of the likelihood of a major hospitalisation or fatal outcome (as demonstrated in the mass data section of this report) and deserves special attention.

It should be remembered that rollover occupants in this study consisted of those who essentially remained inside the vehicle; totally ejected occupants were ruled out of this study because of the difficulty of identifying vehicle involvement in their injuries. It is accepted, therefore, that the severity level of injury for this sample may be less than that observed overall for rollover injuries as those ejected have been shown to be at greatest risk of severe injury and death (Campbell 1981; Huelke and Compton 1983; Green et al 1987)). The findings, however, are most relevant for assessing likely vehicle improvements in minimising injury to these occupants.

Vehicle rollovers observed so far predominantly involved full turn (or greater) and end-to-end rollovers. Partial turn configurations were much less frequent amongst this hospital sample of occupants. It was not possible to calculate impact velocity for these crashes using CRASH 3.

6.5.1 Injuries and Contacts

The most frequent injury from a vehicle rollover was to the occupant's upper limbs and head (133% and 117% respectively), followed by face and spine injuries. Severe injuries were recorded to heads, chests, and spines. The roof surface, side glazing, and door panels were the major injury sources for these occupants, although exterior contacts were also quite common in roughly two-thirds of all rollover injuries. Because of the limited amount of data available, it was not possible to break down the types of body region injuries and their sources inside the vehicle by the various seating positions at this time.

There are only a few reports in the literature of the types of injury sustained by car occupants in rollover collisions. Huelke and Compton (1983) reported severe (AIS<2) injuries to the abdomen (54%), chest (47%), and head/neck (22%) in a study of 836 rollover patients using NASS data. However, the majority of these occupants were unrestrained, hence it is difficult to relate the two sets of findings. Fan and Jettner (1982) also reported severe upper torso (38%), head and face (15%), abdomen (20%), and spine (6%) injuries for patients, although it is not clear whether these involved only rollover crashes.

The contact source findings appear to be similar to those reported by Heulke and Compton (1983) who found that roofs and doors (presumably including glazing areas) accounted for 32% of their severe injuries to "non-ejected" occupants in rollover collisions. The greater number of steering contacts they reported (15% cf. 0%) may well be a function of the substantial number of severe injuries which could not be attributed to any particular vehicle component in this study, as well as differences in seat belt wearing behaviour between the two studies.

Given the small number of cases investigated so far, it will be important to see whether these findings hold when more case details have been collected.

6.5.2 Rollover Integrity

Distortions in the rollovers investigated so far have involved a substantial number of roof and pillar support intrusions and/or deformations, resulting in severe injury contacts for these occupants. While some of these collisions involved full (and multiple) turns, and end-for-end rollovers, the vehicles appeared to fail in offering structural protection to the vehicle's occupants. This needs a more detailed analysis when there are more cases available for analysis.

6.5.3 Entrapment and Ejections

For reasons previously explained, it was not possible to make any definitive statements at this time about entrapments or ejections in rollover collisions.

6.5.4 Conclusion

There are too few cases yet to make much out of the injuries and points of contact for those hospitalised from car rollovers. There was a suggestion that head injuries predominated amongst all occupants involved in rollover collisions and that the roof, door panel and side glazing of the vehicle was the major source of severe injury. However, there was a large number of cases involving contact with an exterior object or where an injury source could not be determined, which might explain at least some of the difference observed between these results and the findings of others in the literature; in particular, why the steering assembly did not have any influence on injuries sustained, especially to drivers.

6.6 OTHER FINDINGS

There were one or two other areas of interest in analysing the results of the crashed vehicle study that need commenting upon.

6.6.1 Injuries by Vehicle Mass

The data collected in the crashed vehicle study (hospitalised patients) was not suitable for deducing relationships about crash involvement rates by vehicle mass or size. However, it was possible to compare the various types of injuries sustained by the occupants and which points of contact within the vehicle caused these injuries for each of the different sizes of vehicles that were inspected.

Previous research in this area suggested that the injury outcome of occupants of larger vehicles should be better than that of small vehicle occupants involved in road crashes (Evans 1984; Evans and Wasielewski 1984; Partyka et al 1987; Lui et al 1988). Moreover, the relatively smaller capsule and reduced space that is available for front seat occupants (and drivers in particular) of small vehicles would further suggest that these occupants would be more likely to experience a greater incidence of contacts with the steering wheel and instrument panel than those of larger vehicles.

BODY REGION INJURIES - There were very few differences observed in the injury patterns across the three different sizes of vehicles in the data collected so far. Occupants of small and compact vehicles had marginally more chest injuries (total and severe) than did large vehicle occupants.

In addition, occupants of small vehicles also suffered slightly more severe injuries to the lower extremities than occupants of other vehicles. However, the frequency of head, abdomen, upper extremity, face and spine injuries (including both total and severe injuries) seemed independent of vehicle size.

Nygren (1984) reported significant decreases in the number of injuries to all body regions and the severity of injury by vehicle size for a sizable number (in excess of 320,000) occupants of small, medium and large vehicles involved in road crashes in Sweden. In addition, Hackney and Ellyson (1985) also observed vehicle size differences in HIC and chest G values of occupant dummies for 159 crashed cars in the New Car Assessment Program (where values decreased as the size of the vehicle increased). Further analysis using a larger database than that available at present is clearly required on these data. The literature suggests that this analysis needs to incorporate different crash configurations, relative masses of the striking and struck vehicles, occupant age, seating position, and delta-V differences.

INJURY SOURCES - Again, there were only marginal differences observed in the points of contact and injury/source interactions between occupants of small, compact, and large vehicles in this study. Minor seat belt injuries were more common in small vehicles, although not for severe injuries. Severe injury contacts with the steering wheel, though, particularly involving the chest and abdomen, were more frequent for small than large vehicles. Contacts with interior surfaces (roofs and doors), however, were more common for large than small vehicles for both total and severe injuries (especially involving the chest and abdomen).

Appel and Wustemann (1982) were the only investigators to report on small (<1000kg) and large (>1000kg) vehicle contact effects. They reported more contacts with the instrument panel for small vehicles and interior surfaces for large vehicles, as found here. However, there were no appreciable differences in the percentage of contacts with the steering wheel for either small or large vehicles and, contrary to the results here, they noted a greater percentage of belt injuries for large than for small vehicle occupants. It is not clear from their results, though, what severity of injury they included in these findings.

CONCLUSION - While some of the findings from 227 vehicle crashes must be treated with some caution because of the small numbers of cases in many of the cells, there was, nevertheless, a hint in these data that occupants of larger vehicles had slightly fewer chest and upper extremity injuries than the occupants of small vehicles. However, there did seem to be a small increase in the frequency of head and face injuries for occupants of large vehicles.

Seat belts and steering wheels seemed to be associated with more injuries to small car occupants while large car occupants were more at risk of injury from the interior surfaces. Many of these findings are difficult to explain in terms of vehicle size or mass alone and suggests it may be compounded with different crash configurations, striking vehicle, occupant age, seating position, and possibly delta-V differences. Further research is warranted here with additional data to help clarify these issues.

6.6.2 Injuries and Drive Configuration

The results of the analysis of vehicle integrity by front- and rear-wheel drive was discussed earlier in the frontal impact section. It was noted that because of the correlation between vehicle size and drive configuration, analysis of drive configuration effects needed to be very controlled, and it was only possible to compare differences for compact vehicles.

It had been hoped to undertake an analysis of the type of injuries and contact sources by vehicle drive. However, given the data constraints at this time, it would not have been a meaningful exercise and was not undertaken. It is hoped that this will be possible in future when more data are available.

6.7 CONCLUDING COMMENT

A number of important findings have come out of this study. However, it should be stressed that with only 227 crashes investigated so far, some of these findings must only be preliminary. The decision to continue the crashed vehicle program is clearly warranted from these findings.

Furthermore, the crashed vehicle study results need to be viewed in context with the mass data analysis before recommendations can be made about possible countermeasures to reduce the injuries sustained by occupants of modern passenger cars. This will be done in the next Chapter.

7. GENERAL DISCUSSION & RECOMMENDATIONS

This final chapter of the report brings together the findings of the literature review, mass data analysis, and the preliminary results of the crashed vehicle study to provide a detailed account of injuries and sources of injury to occupants of current generation vehicles involved in road crashes. In addition, in-vehicle solutions to minimise occupant injuries will be highlighted, although no attempt will be made to prioritize these in terms of costs and benefits. Additional research in occupant protection is also discussed at the end of this chapter.

As in previous chapters, emphasis will be placed on the level of occupant protection by seating position for the various crash configurations observed in these data. However, given the preliminary nature of the current findings from the crashed vehicle study, occupant protection for **front seat passengers in frontal impacts** (drivers and front-left occupants only) is of primary interest at this stage as these represented more than half the number of hospitalised occupants in the study.

A limited number of supplementary volumes are available which describe each individual case inspected in the crashed vehicle inspection program. These cases should be used to illustrate the particular problems experienced by front seat occupants in frontal crashes.

7.1 FRONTAL IMPACTS

The importance of frontal collisions was evident in both the mass data and crashed vehicle study analyses in the percentages of these crashes where an occupant was hospitalised (65% and 60% respectively). Moreover, these cases often involved severe injuries (AIS>2) and were over-represented in fatal and long-term hospital outcomes. Clearly, frontal impacts deserve primary focus in efforts aimed at improving occupant safety.

7.1.1 Injuries Associated With These Crashes

The mass data analysis and the crashed vehicle study identified a number of body regions at risk of injury (and severe injury) for front seat occupants involved in frontal crashes. These are discussed below in their general order of importance.

HEAD INJURIES - Injury to the head was the most common body region injury associated with front seat occupants deaths from this crash configuration, and the third most frequent injury (often severe) for those hospitalised. Given the often life threatening nature of these injuries, the frequency with which they are still occurring to front seat occupants wearing a seat belt is very disturbing.

As noted in the literature review, the inability of the present restraint system to restrain the head often leads to contact with the steering wheel for drivers, as evident from the findings from the crashed vehicle study (26% patient involvement). Moreover, while front-left passengers are relatively free of steering wheel contacts, they still recorded a substantial number of head injuries from the windscreen, instrument panel, console and pillar. Obviously, this is an area where greater attention needs to be placed in any future improvements in occupant safety.

CHEST INJURY - Severe injury to the chest was also frequently observed for drivers and front-left passengers killed or hospitalised from frontal impacts. These injuries were often of severe levels and frequently associated with long-term hospitalisation for the people involved.

Past research by Mackay (1977) and Arajarvi (1988) showed that these injuries can involve aortic rupture, heart and lung ruptures and contusions, either from internal fractures of the sternum or ribs, or from external penetrations. While these injuries have been reportedly declining with the increasing use of seat belts (Hartemann et al 1977; Arajarvi 1988), the results of this investigation, nevertheless, show that they are still occurring often enough to be of concern for front seat occupants involved in frontal crashes.

ABDOMINAL INJURY - Abdominal injuries were less frequently associated with front seat occupant deaths from frontal crashes than injuries to the chest in the data collected here. However, they were the most frequent severe injury reported for hospitalised drivers and were relatively frequent for all and severe injuries to hospitalised front-left seat passengers. Moreover, the crashed vehicle study results demonstrated that these injuries were often linked with steering wheel, instrument panel, and seat belt contacts.

Appleby and Nagy (1989) noted that abdominal injuries from road crashes involve contusions, laceration or rupture of the liver, spleen, jejunum, ileum, colon and associated mesenteries, sometimes involving fracture of the lumbar spine. Seat belts have been commonly associated with these injuries (Garrett and Bernstein (1962), Henderson et al (1977), Lowenhielm and Krantz (1984), Christophi et al (1985), although Ryan and Raggazon (1979) reported that the incidence of these injuries is low.

LOWER EXTREMITY - The most frequent injury recorded in the mass data for front seat occupants hospitalised from frontal crashes was to the occupants' lower extremities. In addition, the crashed vehicle study showed that many of these injuries were severe (AIS>2), and often associated with contact from the instrument panel, floor, and the steering column (for drivers).

There is not a vast literature available on what forms these injuries take. From this study, however, lower limb injuries frequently included damage to the knee (44%), the ankle or foot (30%), lower leg (24%) and the upper leg (2%). In many instances, these injuries were in conjunction with severe intrusions of the instrument panel, steering column or the engine "fire-wall".

Lower limb injuries, too, have been associated with "submarining" where the occupant slides under the seat belt and contacts the lower portion of the instrument panel or the steering column (Adomeit and Heger 1975; Adomeit 1979; Mackay 1988). In many instances, submarining is promoted by unsatisfactory seat belt geometry (Newman et al 1984). There is clear evidence that injuries to the lower limbs need specific attention to minimise these often disabling, painful and expensive injuries.

UPPER EXTREMITY - Upper extremity injuries were especially a problem for front-left seat passengers, involving both major and minor injury severities. Types of injuries included the wrist or hand (37%), shoulder (22%), forearm (15%), elbow (12%), and the upper arm (10%). The contacts varied for these injuries but included instrument panels, interior surfaces (notably the roof and door panels), seat belts, and the windscreen & header rail.

There was practically no literature on these types of injuries, except for some discussion of injuries to the shoulders and upper arms from inappropriate belt geometry (Wells et al 1986). Given that hands and forearms are commonly involved in upper extremity injuries to front seat occupants, it would be worth conducting further investigations of the relation between hand injuries and belt geometry when additional data is available.

SPINAL INJURIES - The incidence rates for spinal injuries were not particularly high compared to other injuries, but still of sizable concern, especially for severe injuries to front-left passengers in frontal crashes, including those restrained. Unfortunately, though, it was not possible to identify an injury source accurately for most of these injuries. As many did involve a fracture and the serious ramifications associated with this, the scope for reducing spinal injuries needs to be considered further in future occupant protection improvements.

The literature review reported several studies of cervical spinal fracture involving vertebrae C1, C2 and C3, loosely referred to as "hangman's fracture", where the seat belt was judged to have caused of the fracture. However, there were also reports of similar fractures where no seat belt was involved. There was one case in the crashed vehicle study which appeared at first glance to be a "hangman's fracture" candidate. However, closer inspection revealed a multiplicity of vehicle factors involved where the seat belt was only one factor.

For more minor outcomes, however, there was a considerable number of whiplash injuries to the neck involving belted front seat occupants. While most of these injuries did not require hospitalisation of the occupant, they are often long drawn-out claims and involve considerable pain and discomfort to those involved. It is not clear yet what the mechanisms are behind whiplash injuries (Fildes and Vulcan 1990), but severe movements of the head and associated damage to the soft tissue in that region is often involved. As Larder et al (1985), noted, two-thirds of whiplash cases do not involve head contact and around 40% of them result in neck pain for at least a month. This suggests there is scope for substantial improvement here.

Lumbar spine injuries were not very common for drivers and front-left passengers, although some were observed for the few centre-rear cases investigated. These will be the subject of a further separate report.

7.1.2 Common Points Of Contact

The crashed vehicle study was able to identify a number of common points of contact for front seat occupants injured in frontal crashes and these have been summarised below.

STEERING WHEEL - Steering wheel and hub contacts were over-involved for drivers in frontal crashes, especially those involving severe (AIS>2) injury. As noted above, these contacts usually were associated with head, chest, and abdominal injuries. Moreover, steering wheel assemblies distorted in 28% of crashes in either a longitudinal, lateral or vertical direction, thereby promoting body contact. Wheel damage varied from relatively minor distortions from body impact to complete destruction of the wheel and spoke system from the hub.

Steering wheel injuries have been previously reported by Jones (1982), Backaitis and Dalmotas (1985), and Appel and Wüstermann (1986). While there were differences in the rates of involvement per 100 patients, it was argued that these differences were probably a function of the way injuries from the belt and steering wheel were coded. Not surprisingly, there were very few reports of contacts between the steering wheel and the front-left passenger, either here or in the literature.

INSTRUMENT PANEL - The instrument panel was the most common source of injury for all and severe injuries to front-left passengers, and was heavily involved in driver injuries too. Upper sections of the instrument panel were involved in upper limb contacts by both drivers and front-left passengers, while the latter group also recorded a substantial number of chest and abdomen injuries from this source. Lower panel contacts were observed with the abdomen and the lower limbs for front seat occupants, including all and severe injuries.

Similar rates of contact between occupants and instrument panels have been reported in the literature. While padded upper areas of the instrument panel are standard features in modern passenger cars, there is clearly scope for further improvements. In addition, the brittle plastic materials commonly used in these components are often injurious in a crash and alternative materials (eg, sheetmetal) need to be considered in areas frequently contacted by front seat occupants in frontal crashes.

SEAT BELTS - Seat belts were a prevalent source of injury to the chest, abdomen, and to a lesser extent, the upper extremities, for front seat occupants involved in frontal crashes. While these injuries tended to be minor, there was, nevertheless, a notable number of severe chest and abdomen injuries from this source. The need for seat belt improvements was alluded to earlier in the review of the literature. It was argued that improvements needed to focus on overall effectiveness, reductions in secondary impacts, minimising the possibility of submarining, and limiting contact pressure to reduce chest injuries. The results of this study only confirm the need for all of these improvements, and point to the need for better seat belt geometry and reduced total extension of the belt before locking up and during loading.

FLOOR AND TOE PAN - Toe pan and floor intrusions and/or distortions occurred in three out of every four frontal crashes where a front seat occupant was hospitalised in this study. In many instances, these intrusions involved the front wheels being driven back into the passenger compartment. Occupant injuries to the lower leg occurred in roughly half of these cases often involving severe injury (12 percent of cases). This is a problem of major concern, involving structural inadequacies in this region of many current generation vehicles in this country and deserves immediate attention.

In addition, there were several instances of occupant knee and lower leg contacts with the lower region of the instrument panel and steering column (i.e., these items plus attachments such as stereo units, heating and cooling devices, switches and fuse boxes, and parcel shelves). While improvements to minimise injury in these structures have already been suggested (eg, safer materials), occupants' safety would also be enhanced if these regions were free of any local protrusions or obstacles.

WINDSCREEN AND HEADERS - Windscreen and header contacts tended to result in less severe injuries to front seat occupants, although there was still a substantial number of minor injuries from this source. While many of these contacts involving injury to the face, head and upper limbs were to unrestrained occupants, there was however, still a sizable number of these contacts still among belt wearers (one in four drivers and one in two front-left passengers). This suggests there is insufficient clearance between front seat occupants and the windscreen in a proportion of current generation vehicles, and/or the seat belt system is allowing more forward movement than is desirable.

The marked decrease in the percentage and severity of windscreen and header contacts with that reported from earlier studies (eg, Jones 1982) is testament to the benefit of seat belts in vehicle occupant protection. However, there is scope for further improvements in windscreen design, reduced seat belt extension, and improved padding of the windscreen header rail to prevent injury.

CONSOLE - Roughly one in four drivers and one in five front-left passengers recorded a contact with the centre console, involving minor injury to most body regions. Furthermore, there were no observable differences between belted and unbelted occupants. This finding has not been previously reported in the literature reviewed in this study. Closer inspection of the cases revealed that many of these contacts were with the centre console extension of the instrument panel and similarly involved inadequate materials and protruding switches, brackets, etc. More attention needs to be clearly placed on the safety design aspects of these units, especially in the materials used, minimising protrusions, and better padding.

INTERIOR SURFACES - Door and roof panels were involved in a number of injuries to drivers and front-left passengers in frontal crashes. Some of these injuries may have been avoided if door handles and roof attachments were more smooth, by providing safer structures overall, and additional padding. The need for these improvements is more likely to be paramount in side impact crashes and rollovers and will be discussed in a later report.

7.2 POTENTIAL FRONTAL CRASH COUNTERMEASURES

The previous discussion has summarised the injuries sustained by front seat occupants of current generation passenger cars involved in frontal crashes and the sources of these injuries within the vehicle. A number of countermeasures (most of which have been fully developed and are currently available) are possible here.

7.2.1 Steering Assemblies

The steering wheel and assembly has been shown to inflict considerable injury to drivers of cars involved in these frontal crashes. This is in spite of the fact that most of them (84%) were properly restrained. There are a number of steering wheel and assembly countermeasures worthy of consideration.

PADDED 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 front seat occupants involved in frontal crashes. The Transportation Road Research Laboratory in the U.K. and Volvo have developed units which are now in current production vehicles in the U.K. (Marina, Metro, etc.) and Sweden (Volvo 700 series). While it is still too early to assess the safety benefits of these devices fully, preliminary indications seem promising. Recent discussions with the TRRL in the U.K. suggested that the increased cost of these padded wheels as production units on vehicles was small (if anything at all) compared to previous steering wheel designs.

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.

Mechanical and electronically activated units are currently available overseas and are already fitted to cars such as Volvo, Mercedes-Benz, and Audi, and are being contemplated by other European manufacturers as well. The Volvo mechanical unit manufactured by Autoliv in Sweden is installed in the seat and attaches to the seat belt stalk, pulling it down in the event of a crash. The electronic unit in some Mercedes-Benz models fires a charge which retracts slack in the belt system when the crash sensors are activated shortly after impact. Audi fit a mechanical cable device in some of their models which pulls down on the belt stalk if the engine moves towards the passenger compartment.

While there has been some discussion about the consequences of the tightening load on occupants injuries, the overwhelming conclusion is that the additional reverse load forces are more than offset by the reduced acceleration forces on the occupant's chest during the collision.

SUPPLEMENTARY AIRBAGS - An airbag as a supplement 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 potential injury reduction measure for front seat occupants in frontal crashes.

Current thinking in Europe, where seat belt wearing rates are similar to Australia, is that a small airbag (the "Eurobag") is a worthwhile addition to a 3-point restraint system as a **supplementary restraint** system to reduce the incidence and severity of head, chest, and abdominal injuries to drivers by cushioning the impact with the steering wheel. This airbag need not be as large nor be deployed as rapidly as the primary restraint airbag and the sensing mechanism can be much simpler. It is claimed, therefore, that it should be cheaper to produce.

On the other hand, larger airbags are specified in the USA with more stringent requirements for deployment and reliability as **passive restraints** for drivers and front seat passengers which do not require any action on the part of the occupant. It has been argued that these airbags are not necessary in Australian vehicles because of our high wearing rates of seat belts. The crashed vehicle study, however, showed that 17 percent of front seat occupants who were hospitalised from their crashes were unrestrained. Hence, the full size airbag would be of benefit to these occupants as a passive restraint while offering supplemetary benefits to those who are already restrained. The question, then, becomes one of relative costs.

Kallina (1990) claimed that, in fact, the Eurobag would not be cheaper to produce than the U.S.A. airbag if economies of scale are considered (the Eurobag cost reductions in equipment would be more than offset by the savings of a larger production run of U.S.A. airbags if they were universal). Moreover, he argued that the passive restraint airbag would offer additional safety benefits over the Eurobag in offset frontal crashes and would also be available to front seat passengers as well as drivers. Nevertheless, there are airbag manufacturing companies in Europe and the U.S.A. currently researching and developing a Eurobag.

In a recent edition of Status Report (Insurance Institute for Highway Safety 1990), it was claimed that the Japanese manufacturers are producing driver side airbags (passive restraint devices) as supplementary restraints in many of their cars sold in Japan and have plans to provide passenger side airbags within a very short time span. Toyota and Honda vehicles were singled out in this report. These manufacturers have clearly responded to the added safety benefits of having an airbag as well as a manual 3-point restraint system in their current and future production vehicles in Japan. It is hoped that these improvements will also be available for the equivalent vehicles marketed in Australia.

Contrary to many of the other frontal countermeasures discussed here, the supplementary airbag is a moderately new product which may need further development before it becomes a viable measure for drivers (and perhaps front-left passengers) in Australian vehicles. In the meantime, however, it would be helpful if all manufacturers who currently produce cars with airbags for the U.S.A. and other local markets (albeit left-hand drive configuration), were to offer an airbag is an option for Australians who wish to purchase such a device (ie, a "mandatory option" requirement).

AUSTRALIAN DESIGN RULE 10/01 - Current Australian vehicle design standard ADR10/01 specifies maximum longitudinal movement allowable in a frontal barrier crash. The results of this study show that in roughly one in six cases, there was movement of the steering column in a vertical (upward) or lateral (sideways) plane as well.

The current Australian Design Rule does not cover movements in these directions. Yet there were many examples of injury from contact with the steering wheel or column that may have been avoided had the assembly not penetrated these occupant spaces. It would be worthwhile evaluating the possibility of including maximum movements in a lateral and vertical plane for steering assemblies in ADR 10/01.

NO STEERING WHEEL - Of course, the absence of a steering wheel entirely (replaced by other controls in a less vulnerable region) is yet another option to reducing these injuries. The steering wheel is a tradition which motorists have come to expect. Technology is available to replace this unit with a joy-stick or a "mouse" arrangement that could be positioned in an area to maximize control and occupant safety, thereby removing this source of potential injury to the driver.

7.2.2 Improved Restraint Systems

The need for improvements to existing seat belt systems was highlighted in the literature review and in the injury and contact evidence here. There are still a substantial number of head, chest and abdominal injuries by properly restrained front seat occupants in frontal crashes at impact speeds predominantly below that required by existing standards. Possible improvements to existing seat belt systems are detailed below.

BETTER BELT GEOMETRY - Improved front seat belt geometry is necessary to ensure that belt alignment is optimal and to minimise injury and submarining and belt related injuries. This could be achieved by attaching the lower anchor points of the belts to the seat, rather than on the floor and providing an adjustable D-ring on the B-pillar. There are many European vehicles which already offer this arrangement in their production vehicles. One or two of these vehicles also offer automatic adjustment of the D-ring. Emphasis needs to be placed on ensuring that all vehicles sold in Australia also offer these features.

BELT TIGHTENERS - Mechanical and electronic belt tightening devices were alluded to earlier as a means of preventing occupant contact with the steering wheel and instrument panel. These units have been developed now for a number of years and while they are available on some overseas vehicles, they have not yet become universal features on current generation vehicles. As well as minimising forward movement, belt tighteners can actually reduce the peak loading from the belt on an occupant's chest and abdomen in a frontal crash by minimising bodily accelerations. Their general use in all production vehicles sold on the Australian market should 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 - The design of the front seat has long been proposed as less than optimal for occupant protection. Babbs and Hilton in 1965 released a design for optimizing front seat occupant protection in frontal crashes. While aspects of this design are probably obsolete today, there are a number of features, such as integral seat belts, double shoulder straps, close fitting head restraints, and stronger structure that are still desirable features.

In addition, a more inclined seat cushion angle (to reduce submarining) and additional padding (especially to the rear surfaces) would also help to minimise seat induced injuries to its occupants in frontal crashes. The strength of the seat back and its locking device also needs to be addressed as many of the seats inspected in the vehicles had been flattened backwards. (This was sometimes a function of the rescue operation but also the result of the seat back "letting go" from secondary impact of the occupant during the collision).

SEAT BELT STALKS - Positioning seat belt anchor stalks on the side of the front seat lead to a marked reduction in abdominal injuries from previously noted contacts with the seat belt buckle housing. However, the evidence collected here from the crashed vehicle study suggested that there was still a number of abdominal injuries for both drivers and front-left passengers from the stalk. 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. The need for a seat belt interlock should be examined. The device could be limited to providing a visual and/or audible signal if the seat belt in each seated position is not attached (these systems are currently in use in Volvo and Saab vehicles). Alternatively, they could be made to prevent the car being started if there are unrestrained occupants. The fact that these devices were rejected in the U.S.A. should not prevent serious consideration of them for Australian vehicles, given the cultural differences between these two countries.

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.

INFLATABLE BELTS - The National Highway Traffic Safety Administration (NHTSA) in the USA have also tested an inflatable belt to provide added protection to occupants, especially those vulnerable to chest injuries from the seat belt. No further details are available at this time on these units, although it is envisaged that they could be of more interest as an option or after-market feature for occupants at risk, rather than for uniform use. They may be especially useful for elderly occupants who are at greater risk of sustaining a fractured sternum.

7.2.3 The Instrument Panel

The instrument panel assembly was a well documented problem area for front seat occupants of current generation passenger cars in this study. There are several possible countermeasures currently available to minimise or alleviate these injuries.

BETTER MATERIALS - Better safety materials in the construction of instrument panels is an 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. These sharp broken pieces can cause deep lacerations which could be prevented if smooth sheet metal sections were to be used. In addition, improved padding would also help to reduce the frequency and/or severity of these injuries.

IMPROVED PADDING - 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. ADR 21 specifies the energy absorbing requirements for certain areas of the instrument panel. The evidence collected here suggests it is clearly not sufficient to ensure adequate protection for front seat occupants involved in frontal impacts.

REDUCED PROTRUSIONS - Protrusions were not uncommon on the lower or underneath regions of the instrument panel. In some instances, switches and fuse holders are located in direct line with the drivers' knees and lower limbs, while stereo attachments and air-conditioners are not uncommonly located in line with the front-left passenger's knees and lower limbs.
What this means is that in a frontal crash when the occupant is propelled forward from the inertia of the vehicle prior to the collision, these limbs frequently contacted these protrusions, often with injurious consequences. Naturally, improved restraint systems to prevent submarining and reduce take-up slack as discussed earlier will go some of the way to minimizing forward movement of the legs. Nevertheless, it is also important to ensure that there are no objects or structures in this region that have the potential to cause injury if contacted.

PARCEL SHELF DESIGN - There were instances of parcel shelves located under the instrument panel in some current vehicles that resulted in occupant injury. In many instances, they were simple plastic units very little padding on the front surface. These units are hazardous to occupants in frontal crashes and should either be suitably padded to prevent injury or eliminated.

KNEE BOLSTERS - Knee bolsters are fitted to many American or European models as an added restraint feature for front occupants in frontal crashes. While these units are principally installed in conjunction with passive restraint systems, nevertheless, they can provide good protection for the lower limbs of occupants involved in front crashes. Indeed, installation of these units would satisfy some of the concerns expressed earlier about contact with the lower instrument panel and protrusions.

7.2.4 Structural Improvements

The results of the study have implications for the structural design and strength of many of the vehicles examined. Some of the potential improvements are detailed below.

FLOOR & TOE PAN - The floor and toe pan were found to be the most frequent area of intrusion or deformation scored in this study, occurring to some extent in roughly three-quarters of all frontal collisions inspected in the crashed vehicle study. Moreover, there were a substantial number of lower extremity problems to vehicle occupants, especially involving the feet and lower legs.

In some instances, these intrusions involved the front wheels themselves being forced back into the passenger compartment. Improvements to the structural members in this region to minimise floor deformations and intrusions are clearly warranted to reduce these injuries. The work undertaken by the vehicle manufacturers such as at Daimler-Benz in Germany in relation to offset frontal impacts would seem to be potentially useful here.

INSTRUMENT PANEL - In roughly 60 percent of frontal crashes, the instrument panel distorted in some way (often upwards or backwards into the occupant compartment). In many cases, this happened at impact speeds lower than 48km/h. This points to the need for improved structural design forward of this member to ensure that the impact forces are contained outside the passenger compartment at these moderate crash speeds.

7.2.5 Windscreens, Headers and Interior Surfaces

There were a number of injuries (including severe AIS>2 injuries) as a result of occupant contacts with the windscreen, its header rail, the roof, door rail and the door panel. These injuries were predominantly to the face and upper extremities, and were especially noted for both belted and unbelted front-left occupants. In addition, there were several contacts observed between these occupants and the A- and B-pillar. A limited number of potential countermeasures are suggested.

IMPROVED PADDING - As noted earlier, improved padding of these surfaces would help reduce the incidence and severity of many of these injuries. Digges (1989) argued that 1 inch (2.5mm) of additional padding on these surfaces would lead to a substantial reduction in front seat passenger injuries.

WINDSCREEN LAMINATES - Plastic laminates on the inside of the windscreen are a potential countermeasure against flying glass injuries and perhaps some injuries from contacts with the screen itself. Trials are being conducted in the USA on the effect of applying a plastic film to the inside of glass surfaces to reduce splintered glass from contacting the occupants of cars involved in front crashes. Unfortunately, the results of these tests are not yet available. The findings of one in three non-contact injuries (essentially flying glass injuries) from this study, though, support the desirability of such a treatment.

7.2.6 Barrier Crash Test

The only requirement for a barrier crash test in this country is Australian Design Rule ADR 10/01 which specifies the acceptable levels of longitudinal steering column deformation in a frontal crash test. In addition to an equivalent steering column requirement (FMVSS204), the American Standards also include FMVSS208 which specifies head injury criterion, chest acceleration, and femur loads for a dummy in a full frontal barrier test. There has been some debate about certain aspects of FMVSS 208 including the validity of a full frontal rather than an offset test, and whether 48km/h (30mph) is a sufficient design speed for crash protection.

Some of the suggested improvements detailed above could be achieved by requiring cars to meet the performance requirements of the frontal barrier crash test in FMVSS 208 (but without the passive restraint requirement, ie., allowing the seat belt to be fastened manually). While there is some criticism of the fact that FMVSS 208 does not include an offset configuration, nevertheless, it could be argued that a full frontal crash requirement is better than no standard at all. Naturally, any consideration of an Australian equivalent should also address the matter of full versus offset frontal configurations, and what is an appropriate design speed for adequate crash protection.

7.3 OTHER CRASH AND SEATING CONFIGURATIONS

To date, there have only been 80 side impact crashes and 12 rollovers investigated in the crashed vehicle study. When these cases are broken down by the various seating positions, belt wearing conditions, and other relevant factors, there are only small numbers available for analysis in many of the required important comparisons. These shortcomings were alluded to in chapters 5 and 6 of this report.

A decision to continue collecting data on crashed vehicles has been made recently to increase the amount of data available for analysis. In line with that decision, it would be premature to infer too much from the results obtained so far. A further report is planned in the future which will address the injuries sustained, sources of injury, and vehicle improvements required for all occupants in all crash configurations.

7.4 FURTHER RESEARCH AND DEVELOPMENT

Data shortages and additional research topics were highlighted during this research program and are detailed below for information.

7.4.1 Additional Inspections

The inability of the data to provide reliable robust findings for other than front seat occupants in frontal crashes was alluded to earlier. The most urgent need, therefore, is for the continuation of the crashed vehicle inspection program to ensure sufficient cases for an accurate analysis of side impacts and rollover collisions and rear seat occupants.

On the available evidence, it would seem appropriate in the first instance to double the number of current cases, but to be guided by the data for deciding the ultimate requirements. It might also be opportune to consider a long term crash inspection program to monitor trends in occupant protection in present and future generation Australian passenger cars.

7.4.2 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 is required to provide the information necessary to rank these countermeasures in terms of their importance and cost/benefit ratios to ensure that scarce resources are effectively allocated.

7.4.3 Follow-Up of Specific Injuries

Most of the injury findings reported in this study were summarised into body regions for ease of interpretation and analysis. In doing so, however, the serious nature and the long-term consequences of some of these injuries (ie, spinal and severe head and chest injuries) is glossed over. As a detailed explanation is vital for prescribing the best solutions to these injuries, it would be useful to undertake a more detailed examination of some of the injury data from this analysis. Close attention to seat belt injuries would be especially useful here.

7.4.4 Four-Wheel-Drives and Bull Bars

There was a suggestion in some of the crashes inspected that injuries to passenger car occupants (especially those in near-side impacts) were either made more severe or were the result of direct contact with a bull bar on the bullet vehicle. While the number of cases involving a bull bar was relatively small, the outcomes were particular severe to the occupants involved.

Many of these devices on four-wheel-drive off-road vehicles and trucks are situated at critical heights for passenger car occupants (ie, at head level). Given that these vehicles seem to becoming more frequent on the road, there is an urgent need for a full and detailed assessment of their injury consequences.

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PASSENGER CARS AND
OCCUPANT INJURY

ATTACHMENTS

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 2.1

M O N A S H   U N I V E R S I T Y

Director: Dr A. P. Vulcan

AUSTRALIA

Dear............................

The Accident Research Centre at Monash University is currently engaged in a study of how well vehicles perform in accidents. This work is sponsored by the Federal Office of Road Safety and is an important study aimed at making our vehicles and roads more safe.

This work requires us to examine vehicles involved in road crashes to determine how various parts of the vehicle act 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. First, we would like to talk to you about the circumstances of the crash and to see if you can recall which parts of the vehicle caused your injuries. This will necessarily involve us looking at your medical record file at this hospital.

Second, we would like your permission to inspect the vehicle and to make a number of photographs and measurements of the damaged areas. We assure you that our work will not interfere with your vehicle in any way whatsoever or delay the repair of your car.

The information we collect is for **research purposes only** and will be treated in strictest confidence. It will not be possible for our findings to be made available to the police, insurance companies, etc. as all identifying links to you, the patient, will be destroyed. We may also need to inspect the 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 we have seen into an anonymous set of data without names and addresses. Hence, your confidentiality is further safeguarded here. At the end of our study, we will report to the Government highlighting aspects of car design that might require safety improvements.

We have enclosed a consent form for you to sign authorizing us to obtain details about your injuries and inspect your vehicle. Please sign and date this form if you are willing to participate in this important study.

I hope that you make a swift recovery from your injuries and that you will soon be fully recovered from the effects of the accident.

Yours sincerely,

Peter Vulcan

Dr. Peter Vulcan,
Director.

Accident Research Centre
CLAYTON, MELBOURNE, VICTORIA, 3168 AUSTRALIA TELEX AA 32691 FAX. (61) (3) 565 4007 TELEPHONE. (03) 565 4000 ISD: + 61 3 4000

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 have recently been involved in and consulting my medical record.

SIGNATURE ______________________________

PLEASE PRINT FULL NAME ______________________________

DATED THIS ____________ DAY OF ____________________ 1989

AUTHORIZATION TO INSPECT VEHICLE

I have read through and understand this letter and I HEREBY CONSENT to officers of the Monash University Accident Research Centre inspecting my vehicle, Make ________________________ Registration Number ______________ to examine the vehicle and take measurements and photographs.

SIGNATURE ______________________________

PLEASE PRINT FULL NAME ______________________________

DATED THIS ____________ DAY OF ____________________ 1989

OCCUPANT SAFETY PROJECT
FEDERAL OFFICE OF ROAD SAFETY

MUARC Case No............. HOSPITAL UR No..............

PATIENT DETAILS

Patient...

Address...

........................**Postcode**............**Telephone**...................

Vehicle Registration Number.......................................

Vehicle Owner...

Address...

....**Telephone**...................

Insurance Company...

OTHER VEHICLE DETAILS

Driver..

Address...

....**Telephone**...................

Vehicle Registration Number.......................................

PARTICULARS OF THE CRASH

Location..**Postcode**.........

Date.............**Time**...........**Light**...............**Weather**.............

Police Station..............................**Officer No**....................

Ambulance Type...............................**Case No**....................

PATIENT INFORMATION

MUARC Case No............. HOSPITAL UR No..............

PATIENT DETAILS

Age................ **Sex**................**Driving Experience**..............yrs

Weight..........kgm **Height**.............cm **Seating Pos'n**.................

Other Occupants 1...........................**Outcome**.....................

2...........................**Outcome**.....................

3...........................**Outcome**.....................

4...........................**Outcome**.....................

PATIENTS INJURIES (in order of severity)

1...

2...

3...

4...

5...

6...

7...

8...

9...

10..

11..

12..

Prior Disabilities..

Patient's Account of Injury Causes...

....

....

....

....

....

PATIENT INJURIES

NO.	A.I.S.	SOURCE	FINAL DIAGNOSES

Monash University Accident Research Centre ATTACHMENT 2

VEHICLE & CRASH DESCRIPTION

MUARC Case No.............. HOSPITAL UR No...............

PATIENT'S VEHICLE DETAILS

Make..**Year**................

Model...

Colour.................................**Drive Wheels**......................

Present Location..

....**Tel**..................

Seat Belt Used Yes No **Head Restraint Fitted** Yes No

Prior Damage.......................................**Trailer** Yes No

Your Speed at Crash............km/h **Other Vehicle Speed**...............km/h

OTHER VEHICLE DETAILS

Make..**Year**................

Model...

Colour.................................**Drive Wheels**......................

No Occupants.................**Hospitalised**................................

Present Location..

....**Tel**..................

CRASH DESCRIPTION

Patient's Description of Crash...

....

....

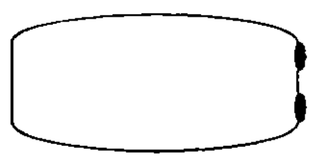
....

....

Crash Diagram

Estimated Impact Force

High [1] Medium [2] Low [3]



➡ Impact

☐ Damage

Rollover ☐

Patient

X Initial

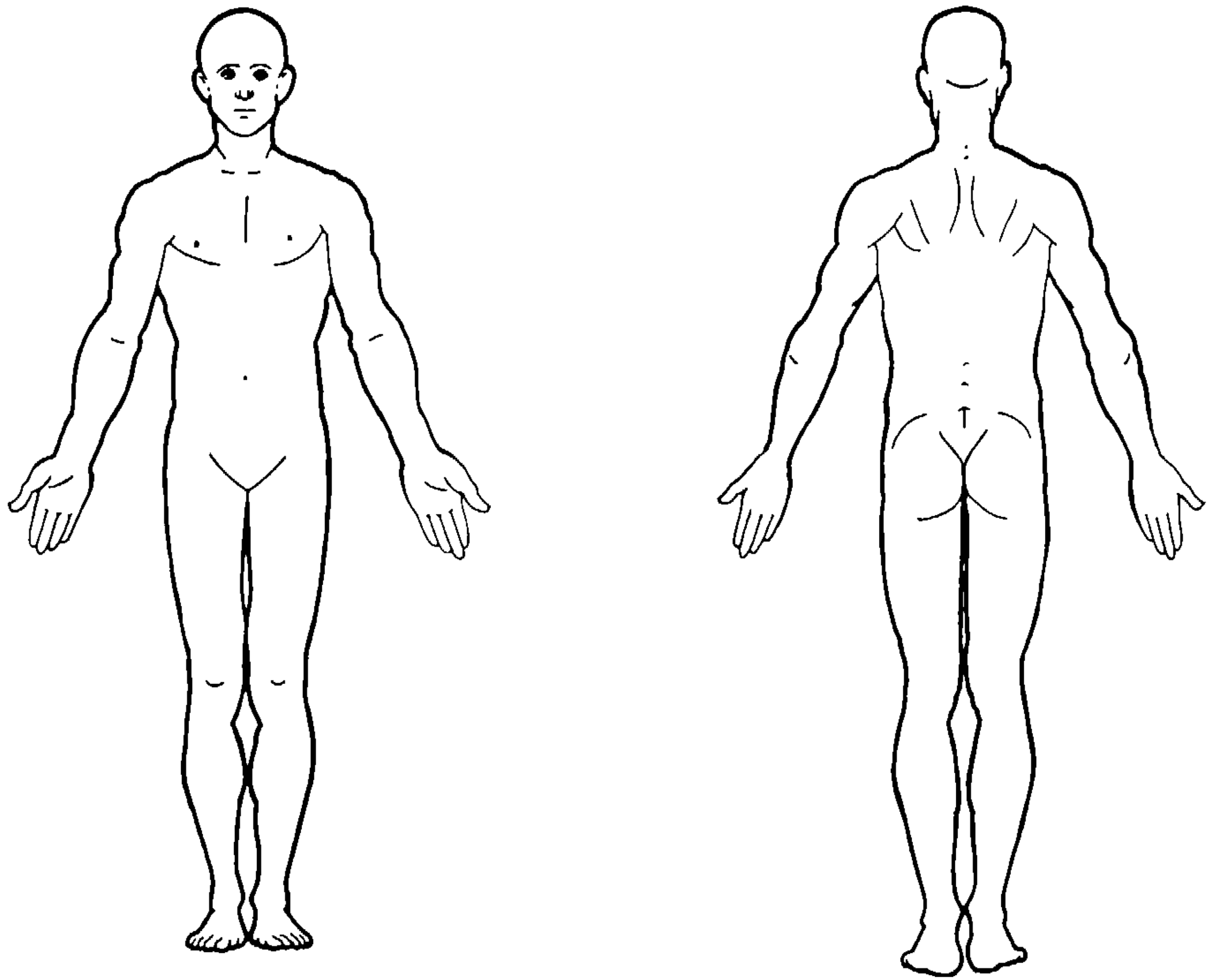
O On Arrival

Movement

Ejected [1] Removed [2] Trapped [3]

OFFICIAL INJURY DATA—SOFT TISSUE INJURIES

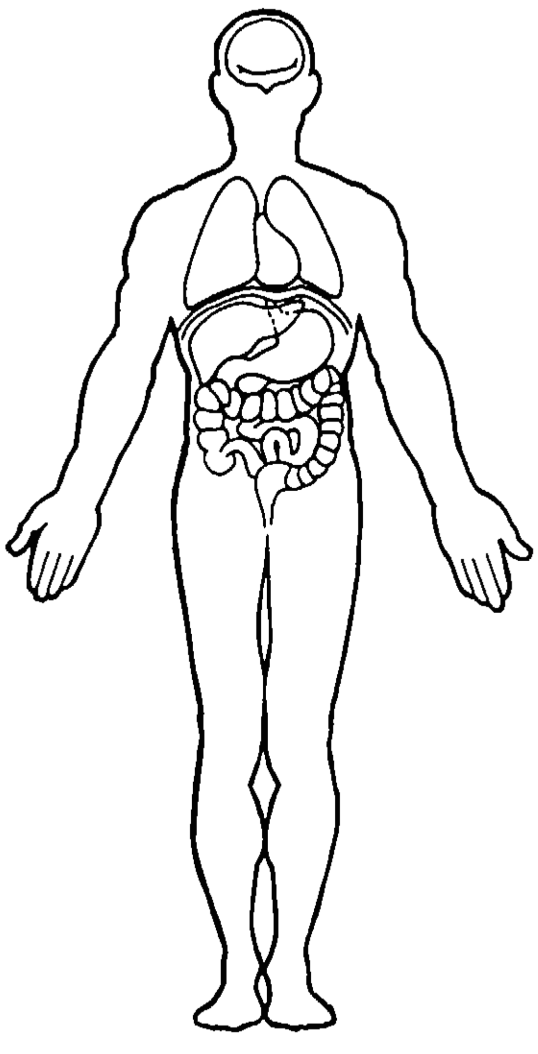
Indicate the *Location, Lesion, Detail* (size, depth, fracture type, head injury clinical signs and neurological deficits), and *Source* of all injuries indicated by official sources (or from PAR or other unofficial sources if medical records and interviewee data are unavailable.)

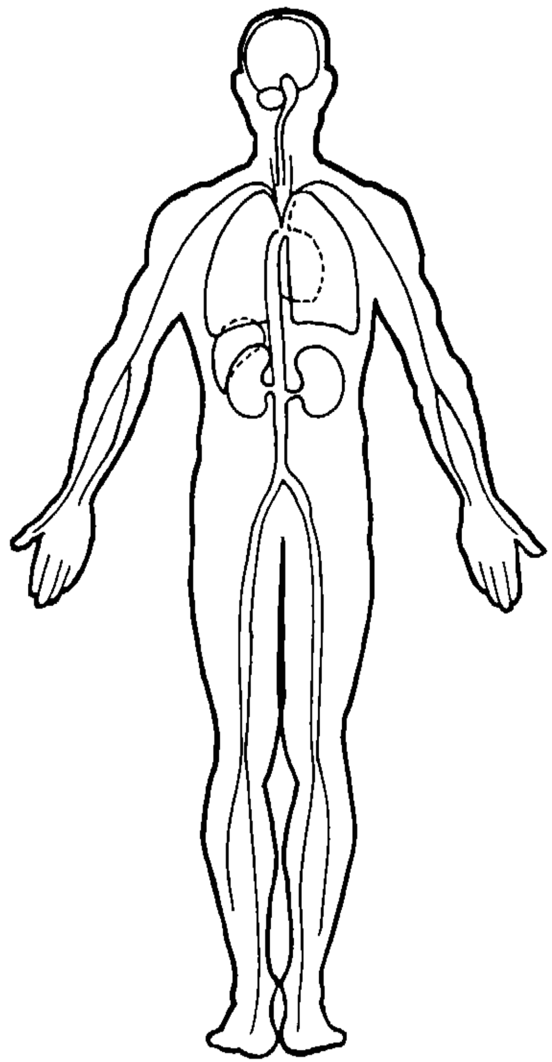


ATTACHMENT 2.7

OFFICIAL INJURY DATA—INTERNAL INJURIES

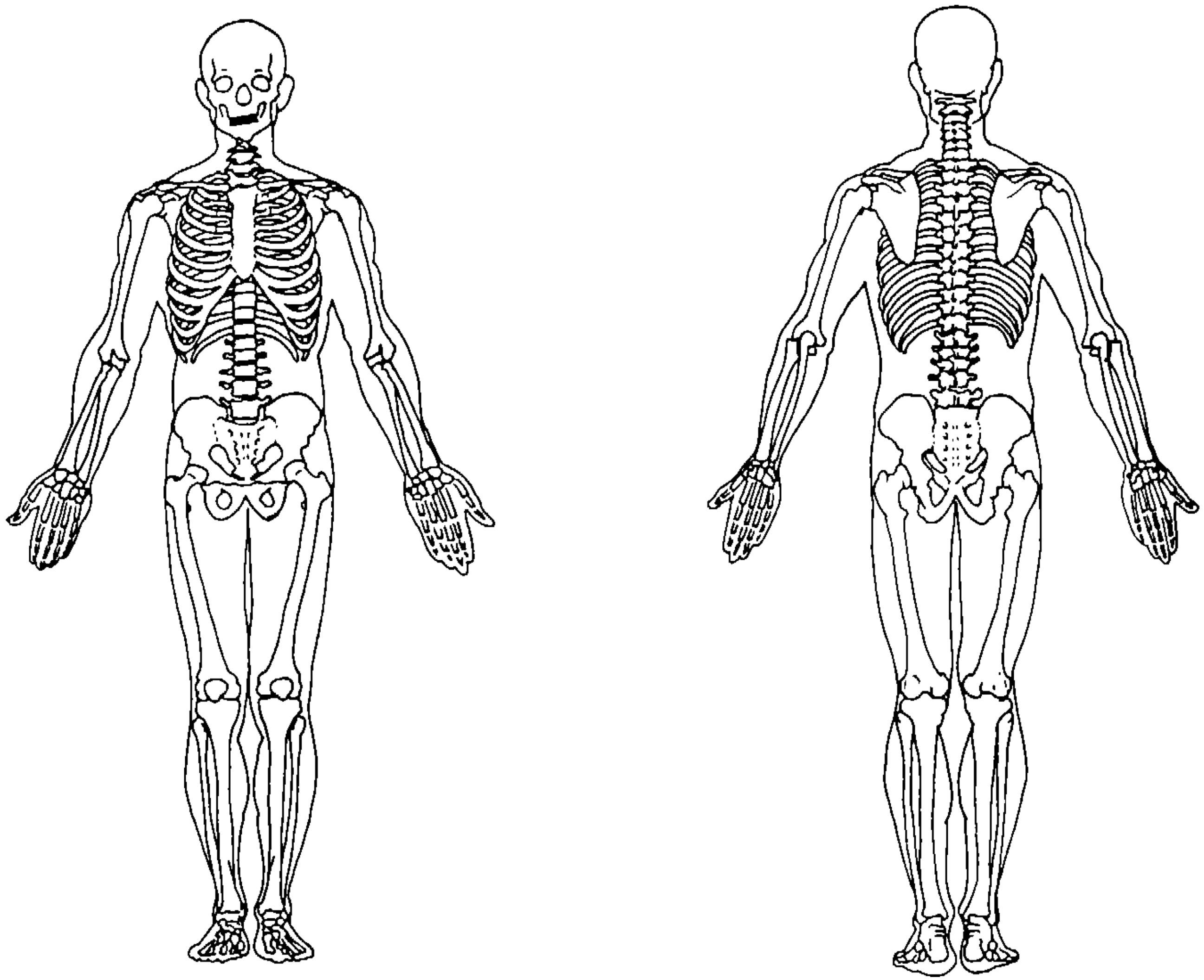
Indicate the *Location, Lesion, Detail* (size, depth, fracture type, head injury clinical signs and neurological deficits), and *Source* of all injuries indicated by official sources (or from PAR or other unofficial sources if medical records and interviewee data are unavailable.)





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.)



ATTACHMENT 2.9

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.

	Source of Injury Data	O.I.C.–A.I.S. 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.

OURCE OF INJURY DATA

FICIAL

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

OFFICIAL

) Lay coroner report
) E.M.S. personnel
) Interviewee
) Other source (specify):

) Police

IJURY SOURCE

ONT

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

T SIDE

) Left side interior surface, excluding hardware or armrests
) Left side hardware or armrest
) Left A pillar
) Left B pillar
) Other left pillar (specify):

) 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

I.C. Body Region

Abdomen
Ankle–foot
Arm (upper)
Back–thoracolumbar spine
Chest
Elbow
Face
Forearm
Head–skull
Injured, unknown region
Knee
Leg (lower)
Lower limb(s) (whole or unknown part)
Neck–cervical spine
Pelvic–hip
Shoulder
Thigh
Upper limb(s) (whole or unknown part)
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 gland
(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

US 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 (Ø and Ƶ)
   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 ******

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 ___ ___ ___

29. 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

30. 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

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

EXTERIOR VEHICLE FORM

NATIONAL ACCIDENT SAMPLING SYSTEM
CRASHWORTHINESS DATA SYSTEM

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 Width (CDC)	Direct Damage Max Crush	Field L	C_1	C_2	C_3	C_4	C_5	C_6	±D

National Accident Sampling System – Crashworthiness Data System: Exterior Vehicle Form

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 ± ___ ___ °

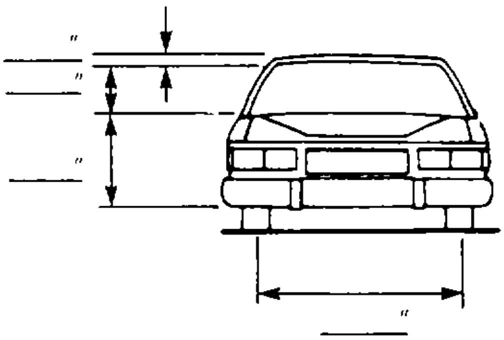
LR ± ___ ___ °

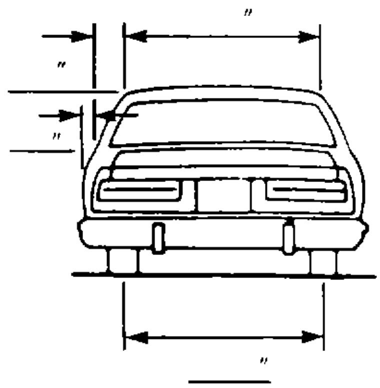
Within ±5 degrees

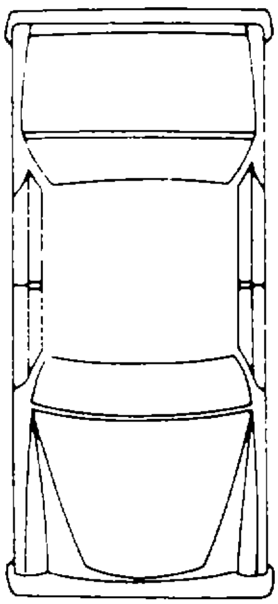
DRIVE WHEELS

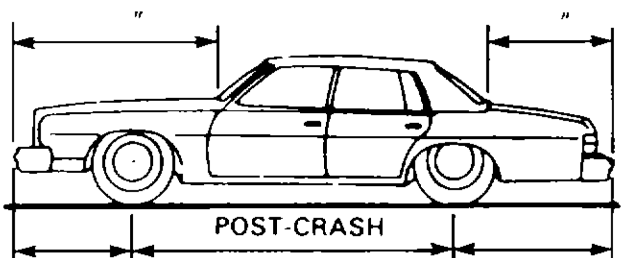
☐ FWD ☐ RWD ☐ 4WD

Approximate Cargo Weight ________



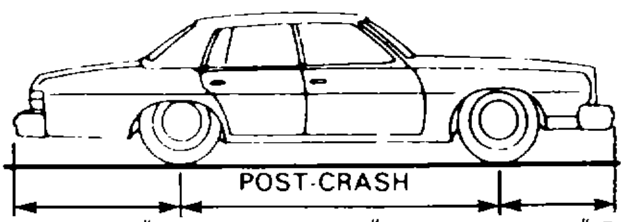






Bumper corner ____ " ____ " ____ " Bumper corner

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.

National Accident Sampling System – Crashworthiness Data System: Exterior Vehicle Form

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

HIGHEST DELTA "V"

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
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)

US 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

Size __

Weight ____ + ____ + ____ = __ __ __ __
(Curb, Occupant(s), Cargo)

CDC __ __ __ __ __ __ __

PDOF __ __ __

Stiffness __

VEHICLE 2

Size __

Weight ____ + ____ + ____ = __ __ __ __
(Curb, Occupant(s), Cargo)

CDC __ __ __ __ __ __ __

PDOF __ __ __

Stiffness __

SCENE INFORMATION

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

VEHICLE 1

Rest Position
- X __ __ __ . __
- Y __ __ __ . __
- PSI __ __ __ . __

Impact Position
- X __ __ __ . __
- Y __ __ __ . __
- PSI __ __ __ . __

Slip Angle __ __ __

VEHICLE 2

Rest Position
- X __ __ __ . __
- Y __ __ __ . __
- PSI __ __ __ . __

Impact Position
- X __ __ __ . __
- Y __ __ __ . __
- PSI __ __ __ . __

Slip Angle __ __ __

VEHICLE MOTION

Sustained Contact [ ] No [ ] Yes

VEHICLE 1

Skidding [ ] No [ ] Yes

Skidding Stop Before Rest [ ] No [ ] Yes

End-of-Skidding Position
- X __ __ __ . __
- Y __ __ __ . __
- PSI __ __ __ . __

Curved Path [ ] No [ ] Yes

Point on Path
X __ __ __ . __ Y __ __ __ . __

Rotation Direction [ ] None [ ] CW [ ]CCW

Rotation > 360° [ ] No [ ] Yes

VEHICLE 2

Skidding [ ] No [ ] Yes

Skidding Stop Before Rest [ ] No [ ] Yes

End-of-Skidding Position
- X __ __ __ . __
- Y __ __ __ . __
- PSI __ __ __ . __

Curved Path [ ] No [ ] Yes

Point on Path
X __ __ __ . __ Y __ __ __ . __

Rotation Direction [ ] None [ ] CW [ ]CCW

Rotation > 360° [ ] No [ ] Yes

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.

29. 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

30. 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

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 Ø.

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 Ø

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)

____

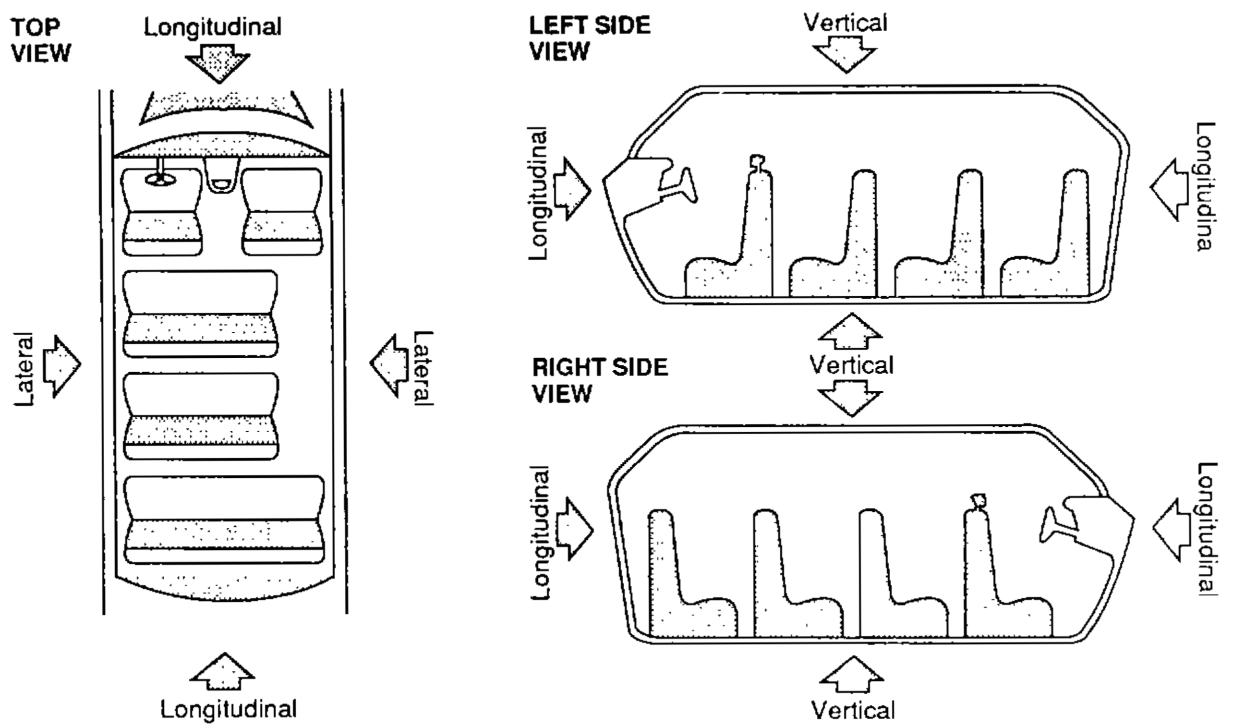
(9) Unknown

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

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

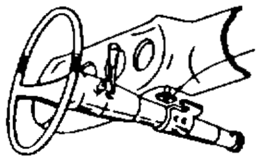
MAGNITUDE OF INTRUSION
- (1) ≥ 1 inch but < 3 inches
- (2) ≥ 3 inches but < 6 inches
- (3) ≥ 6 inches but < 12 inches
- (4) ≥ 12 inches but < 18 inches
- (5) ≥ 18 inches but < 24 inches
- (6) ≥ 24 inches
- (9) Unknown

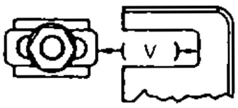
DOMINANT CRUSH DIRECTION
- (1) Vertical
- (2) Longitudinal
- (3) Lateral
- (9) Unknown

STEERING COLUMN WORKING DIAGRAMS

STEERING COLUMN COLLAPSE

Steering Column Shear Module Movement

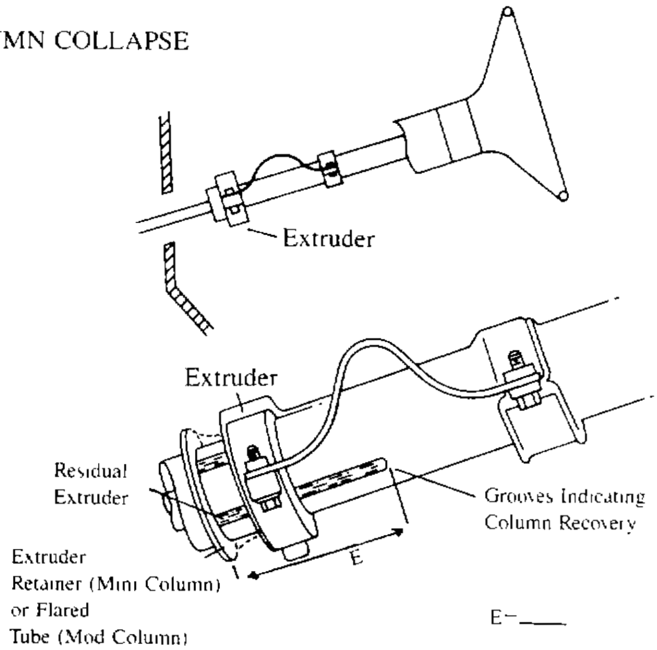




Left ___

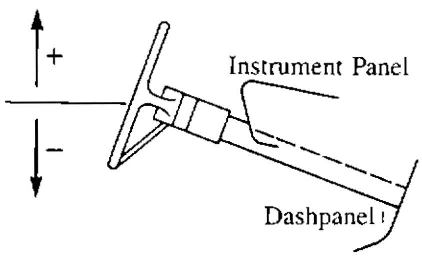
Right ___ V = _______"

Direction and Magnitude of Steering Column Movement

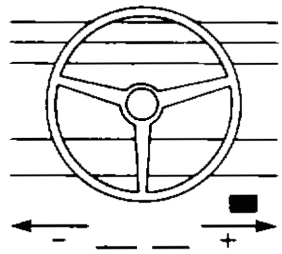


STEERING COLUMN MOVEMENT

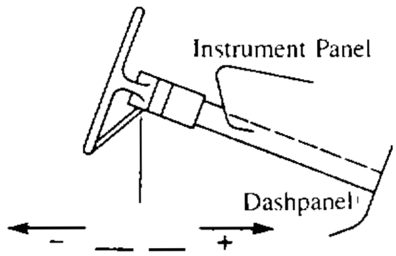
Vertical Movement



Lateral Movement



Longitudinal Movement



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

STEERING RIM/SPOKE DEFORMATION

COMPARISON VALUE	–	DAMAGED VALUE	=	DEFORMATION
	–		=	
	–		=	

National Accident Sampling System – Crashworthiness Data System: Interior Vehicle Form

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.

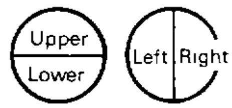
(0) No steering rim deformation
(1-5) Actual measured value
(6) 6 inches or more
(8) Observed deformation cannot be measured
(9) Unknown

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

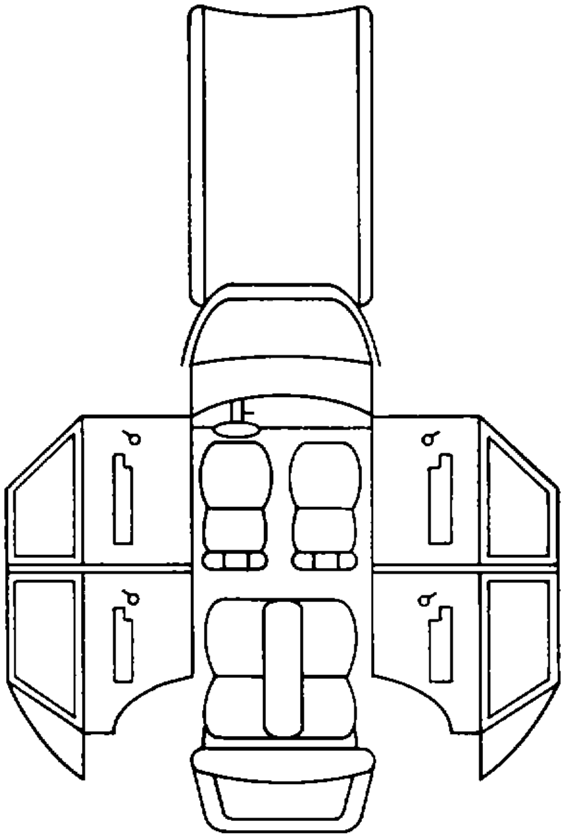
96. Knee Bolsters Deformed from Occupant Contact ___

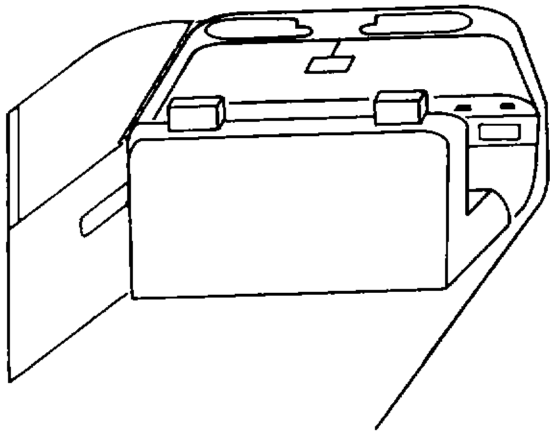
(0) No
(1) Yes
(8) Not present
(9) Unknown

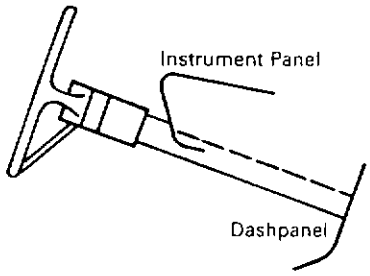
97. Did Glove Compartment Door Open During Collision(s) ___

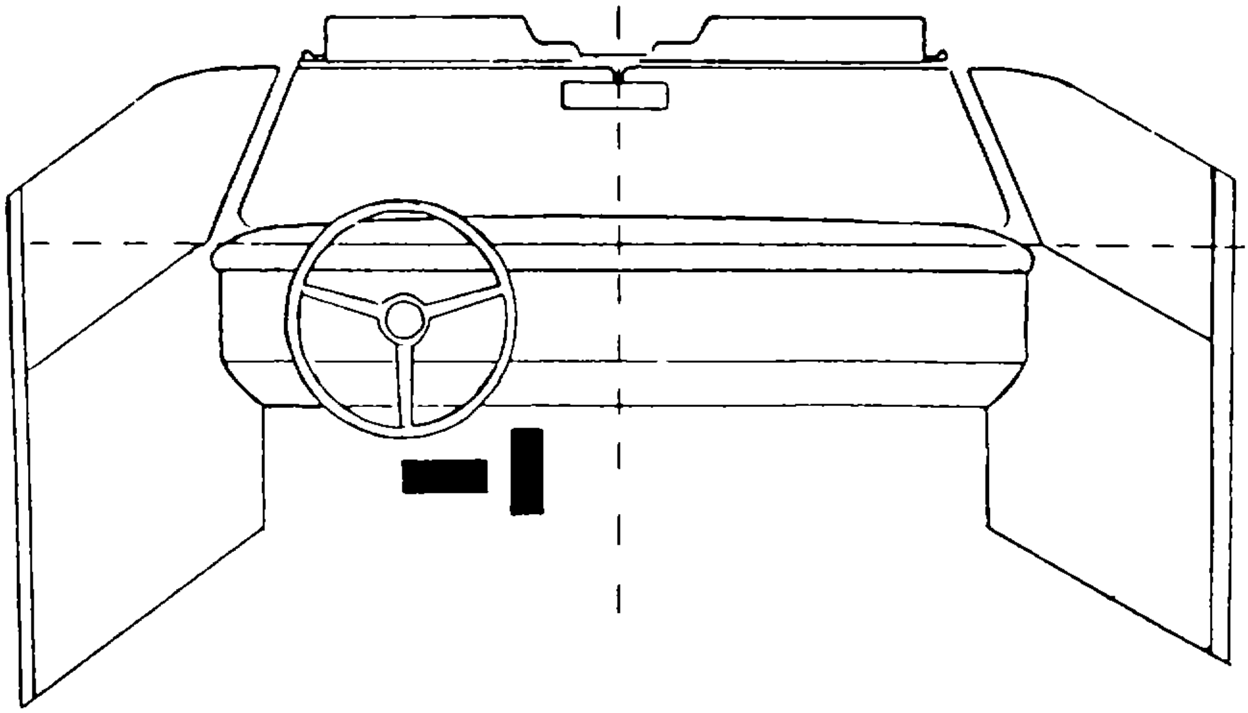
(0) No
(1) Yes
(8) Not present
(9) Unknown

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)

   ____

   ____

   ____

   ____

National Accident Sampling System—Crashworthiness Data System: Interior Vehicle Form

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)