PASSENGER CARS AND OCCUPANT INJURY:
SIDE IMPACT CRASHES

Prepared by

Fildes, B.N.
Lane, J.C.
Lenard, J.
Vulcan, A.P.

Monash University
Accident Research Centre

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Author(s):
Fildes, B N., Lane, J C , Lenard, J. & Vulcan, A.P.

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

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Abstract:
This project set out to assess the extent of protection for passenger car occupants involved in side impact collisions in this country and to make recommendations of ways in which this protection could be improved. A review of the international literature was initially undertaken to highlight current world-wide issues and deliberations and discussions were held with a number of overseas experts on regulation developments in Europe and the U.S.A A case series study of 198 crashed vehicles involving 234 injured occupants was then carried out involving post-1982 passenger cars and derivatives in side crashes where at least one occupant was either hospitalised or killed in the crash. Details were collected on the extent of deformation and intrusion from the crash, the estimated change of velocity during impact (delta-V), the injuries sustained by the occupant(s) and the sources of these injuries from inside or outside the vehicle This report describes the findings from this research and makes recommendations of a range of suitable countermeasures to reduce the incidence and severity of these injuries The relevance of planned side impact performance regulations in the U.S A. and Europe is also considered to the extent possible at this time. A supplementary volume provides a case-by-case summary of each crashed vehicle inspected.

Key Words: SAFETY, ACCIDENT, VEHICLE OCCUPANT. INJURY. TEST METHOD. SIDE IMPACT, EVALUATION

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EXECUTIVE SUMMARY

INTRODUCTION

Side impact collisions are particularly severe types of vehicle crash on our roads. They account for around 25 percent of all injury crashes that occur in Victoria and a much more substantial 40 percent of serious injury crashes (where an occupant is either hospitalised or killed).

Side impacts present a difficult problem for crash protection as there is little structure available between the occupant and the impacting vehicle or object. By comparison, it is reported that the front of the vehicle can absorb up to five times as much energy as the side structure before injury occurs to the occupants of the vehicle.

International developments by governments in side impact protection are focussed on new regulations to improve side impact structure. The US has introduced a new side impact standard which has a three year phase-in period commencing with 1994 vehicles. A technically different side impact regulation is presently being considered for introduction in Europe in 1995.

The present side impact standard in Australia specifies the amount of intrusion permissible from a static load test which results in side impact beams fitted to most Australian vehicles. While Australia is the only country outside of North America to have a side impact standard, doubt exists about how effective this standard alone is for adequate side impact protection.

AIMS OF THE STUDY

With this in mind, the Federal Office of Road Safety commissioned the Monash University Accident Research Centre to examine the level of protection available for occupants seriously injured in side impacts and what can be done to reduce the severity of injury to car occupants involved in these crashes.

The results of the study were to be used to assist the Federal Office of Road Safety in future initiatives aimed at improving occupant protection for Australian motorists. Emphasis was to be given to the need for "performance based standards" and the suitability and desirability of adopting overseas regulations for use in this country.

CRASHED VEHICLE INSPECTIONS

The main source of data used in this study was that collected from the inspection of vehicles involved in real world crashes where at least one occupant was either hospitalised or killed. These inspections commenced in 1989 and concluded in 1992 comprising a total of 501 crashes and 606 injured occupants. Of these cases, there were 198 side impacts and 234 injured occupants which were of interest to this study.

Information was collected on vehicle deformations, injuries sustained and sources of these injuries. Change of velocity during impact was assessed using the CRASH3 computation of Delta-V. All injuries were scored for severity using the Abbreviated Injury Scale (AIS85) procedure and vehicle damage was assessed using the US inspection system specified by the National Accident Sampling System (NASS).

SIDE IMPACT CRASHES

The mean impact velocity change (delta-V) was 35km/h which ranged from 8 to over 96km/h. More than one-third of the values were equal to or below 27km/h, the value equivalent to the new US side impact test for a crabbed crash configuration and two vehicles of equal mass

Impact occurred with the passenger compartment in almost all these crashes resulting in injury Half of the impacts were perpendicular while the rest were obliques Doors, pillars and side panels were commonly deformed and intruded into the cabin in these crashes

Sixty percent of the occupants were drivers, 27 percent front left passengers, while 13 percent were rear seat occupants Roughly two-thirds were seated on the impacted or near side and one-third on the opposite far side

Eighty-seven percent of front seat occupants and 54 percent of rear seat occupants wore seat belts These figures are lower than that observed in the population generally suggesting that seat belts still afford protection to occupants involved in side impact collisions (it may also reflect a tendency for those not wearing belts to be over-involved in side impact crashes)

Ejection rates (where the occupant was observed to be partially or fully out of the vehicle after the collision) were over one-third among those not wearing seat belts but only about two percent among belt wearers. There were fewer non-wearers entrapped than wearers, although it is difficult to interpret this finding in terms of the likely injury consequences for the occupant.

INJURY FINDINGS

Drivers sustained marginally more injuries on average than all other occupants However, there were practically no differences observed in the severity of these injuries across all seating positions Severe injuries to the chest, head and abdomen and pelvis were observed for all occupants regardless of their seating position. These injuries are more likely to be life threatening than others confirming the serious nature of these crashes for occupants

The most common sources of injury to both front and rear occupants was the door panel and frame Other injury sources were the side panel, instrument panel, and side window While seat belts caused injury to approximately one-third of the occupants, these injuries were predominantly minor

Other occupants caused severe injuries most noticeably to front left passengers This was, in part, because there is always another occupant (the driver) present. Exterior objects were more frequently a source of injury for rear seat passengers reflecting the higher non-wearing behaviour and the greater tendency for ejection in the rear seat.

INJURY AND SOURCE ANALYSIS

This analysis enabled the most common injury by source combinations to be illustrated.

For **front seat occupants**, the most frequent severe injury combinations were the chest, abdomen-pelvis and lower limbs with the door panel, and the head with exterior objects Given the relatively high belt wearing rates among these occupants, there were very few differences in the pattern of results for seat belt wearers and non-wearers.

For **rear seat occupants**, the most common severe injury combinations comprised chest, abdomen-pelvis and upper extremities with the door panel, and with exterior objects The three most frequent injury-sources for unrestrained rear seat occupants comprised abdomen-pelvis and chest with exterior objects and chest with the door panel.

There were fewer severe head injuries but more major neck and spine injuries from exterior contacts overall for rear than front seat occupants

In **near-side** collisions, the injury and source patterns were quite similar to those described above for front seat occupants. The near-side door and exterior objects featured predominantly in severe injuries to occupants struck on the impacted side

In **far-side** crashes, however, the most frequent severe injury-source combinations comprised chest with other occupant, chest with far-side door panel, abdomen-pelvis with the seat belt, and head with exterior object. These patterns are consistent with the geometry and forces applied to occupants when struck on the opposing side of the car.

SIDE IMPACT COUNTERMEASURES

This research has identified a number of countermeasures that have the potential to alleviate injuries to passenger car occupants involved in side impact collisions

Side Door Padding

The results above demonstrate the major role the door plays in side impact injuries for both near and far side impacted occupants Improved structure of the door and its surrounds is one area that warrants closer attention (this is discussed further below) However, overseas experts suggest that improved side door padding will help to alleviate many of these severe injuries. Types of padding discussed in the literature vary from soft foams to hard polystyrene materials of varying thicknesses depending on the specific target injury. Some manufacturers wishing to optimise injury reductions have experimented with different combinations of these materials and padding structures It has been claimed that improved side door padding has the potential to reduce thoracic and pelvic injuries by up to 10 percent

Side Door Airbags

Airbags fitted to the door are receiving attention currently overseas They range from a small "sausage-like" unit that aims to reduce chest contacts akin to padding, to a slim but broad bag that rises from the top of the door to the roof offering head, face and shoulder protection These airbags appear to be someway off being production units yet but appear to be attracting considerable research and development effort. Like frontal crash airbags, side airbags have the potential to make significant improvements in occupant protection, especially if they can provide both chest and head benefits

Structural Integrity

Nine out of ten front doors and three out of four back doors were severely intruded in the cases inspected here Moreover, B-pillars and to a lesser degree A- and C-pillars were also commonly distorted in these crashes. While this result is influenced to some degree by the injured population criteria, nevertheless it shows the urgent need for side structural improvement if these injuries are to be mitigated. The Side Impact Protection System (SIPS) developed and promoted by Volvo appears to be a desirable and useful attempt at increasing occupant protection in side crashes. Similar structural developments by other manufacturers would also be of benefit in helping reduce injuries for all motorists

Improved Side Glazing

There were a number of head and face contacts with the side windows and destruction of the window was not uncommon in these crashes The side window is often the last opportunity for restraining parts of the body in these crashes and for preventing injurious contacts with hard outside objects such as the impact vehicle or structure Double side glazing with plastic laminates are fitted to some expensive models overseas for sound insulation These windows would also seem to have the potential to act as a side impact countermeasure Further research to confirm this benefit is warranted.

Seat Belt Wearing

Given that those not wearing seat belts were two to three times over-represented among this injured population suggests the need for increasing further seat belt wearing rates in Australian passenger cars. This is especially true in the rear seat, but even a one percent improvement in the front seat as well is likely to have a sizeable injury reduction on these figures Seat belt warning lights have been recommended in earlier reports and legislated in the new frontal crash regulation ADR69. Efforts to ensure that these devices are effective in increasing seat belt wearing behaviour are paramount for future injury reductions.

Improved Belt Systems

Belt injuries were quite frequent among the occupants, although mainly of low severity. In several cases, it seemed that the belt hardware may have played a role in some of these injuries. This is not too surprising, given belt geometry and the direction of forces. Efforts aimed at reducing opportunities for contact with hardware items as well as methods of ensuring a closer "**coupling**" of the occupant to the seat would seem to be useful.

This coupling might be achieved by pre-tensioning devices and webbing clamps on the belt system although they tend to operate more effectively to prevent forward than side movement. Alternatively, perhaps the seat backs could be more of a sculptured design to offer more resistance to sideways movement by the occupants. This would also act to improve occupants' separation which would have positive benefits also in improved side impact protection.

Instrument Panel Improvements

There were relatively high numbers of lower limb injuries from contacts with the instrument panel This was also reported earlier in FORS Report CR95 for frontal crashes. Previous solutions have included more forgiving lower instrument panels and kneebars which appear to be cost-effective in frontal crashes It seems that these improvements would also be of some value in helping reduce these injuries in side crashes

Reduced Side Impact Opportunities

It was noted earlier that side impacts present a special problem for occupant protection because of the minimum amount of structure between the impacting object and the occupant. Given the severe limitations available for secondary safety improvements, there would seem to be a special case for greater attention to preventing these crashes from occurring

As many of these crashes occur at intersections, attempts to minimise the number of cross-flow opportunities (fewer at grade intersections) would be worthwhile. In addition, the installation of roundabouts and the removal of roadside hazards would also reduce the number of severe side impact crashes.

SIDE IMPACT REGULATIONS

The question of the need for an improved side impact standard to increase the level of structural integrity is paramount to these discussions The responsible authorities in the U.S.A. and Europe have decided on two different test procedures and dummies that cannot be harmonised but which may not be necessarily incompatible for compliance purposes. This raises the question then of whether Australia should also adopt one or both of these two standards to ensure increased protection for Australian vehicle occupants.

In addressing this, it would be helpful to have some indication of the likely benefits and costs for implementing either or both side impact standards. While the available data on the likely injury reductions and the costs of meeting these standards is a little unclear at this stage, it still would be possible to make estimates of these with sufficient accuracy to provide regulation guidance. Given that a dynamic standard is likely to reduce side impact trauma in road crashes, there is clearly a need for further investigations on the advantages of Australia adopting either or both these standards in the foreseeable future.

1. INTRODUCTION

Motor vehicle occupant protection has received considerable attention in this country over the last two decades. Seat belts, improved vehicle padding, head restraints and door beams have all contributed to some degree in reducing the number and severity of vehicle occupant casualties. Yet, vehicle occupant casualties are still the single largest road safety problem in this country. Roughly two out of every three persons killed or injured on the road each year are occupants of motor vehicles (Transport & Communications, 1988).

Passenger cars world-wide are currently undergoing substantial changes in design. Uni-body structure and front-wheel drive is becoming more common amongst new vehicles (American estimates for this design concept are as high as 90 percent for their current vehicles, Fildes, 1988). In addition, small cars with a body weight of less than 1100kg are also becoming more prevalent (1985 census data shows that 45 percent of new car sales were less than 1100kg compared to 42 percent in the previous 1980 census).

Seat belt wearing is also well stabilised at high levels in the front seat of Australian passenger cars (94 percent) although less for rear seat passengers (80 percent) (Ove Arup 1990). Given the relative dearth of recent local research in this area, it is timely then to review the level of safety of modern passenger cars to see if the current level of occupant protection is optimal for all vehicle occupants.

A first report of this project has already been published which examined the level of protection for front seat occupants involved in frontal crashes (Fildes. Lane, Lenard & Vulcan 1991). A number of recommendations were made in this report for which their cost effectiveness was subsequently evaluated (Monash University Accident Research Centre 1992). To date, however, little attention has been paid to occupants involved in side impact collisions. These collisions are known to have an abnormally severe injury outcome for vehicle occupants because of the lack of protection normally available in side structures of passenger cars.

1.1 PROJECT OBJECTIVES

In April 1989, the Federal Office of Road Safety commissioned the Monash University Accident Research Centre (MUARC) to undertake a study into occupant protection of modern passenger cars in Australia. The objective of this study, specified by the Federal Office of Road Safety, was to examine the nature of occupant injuries, as well as vehicle and crash relationships, to the occupants of post-1982 passenger cars involved in road crashes.

Specific vehicle characteristics and design features that could be addressed to offer improved occupant protection for occupants of future vehicles were to be identified. This program of research concluded in 1992 after details had been obtained on more than 500 crashes involving over 600 injured occupants.

The results of this study were to be used to assist the Federal Office of Road Safety in the future development of initiatives to improve vehicle occupant protection in Australia. There was to be a particular focus on "*performance based standards*" where all manufacturers would be expected to meet pre-established safety criteria, rather than measures involving design criteria.

As noted above, a first project report (CR95) was published in 1991 which addressed the protection of front seat passengers in frontal collisions. Subsequently, a second report (CR100) was published in 1992 which examined the feasibility of the measures recommended in the

CR95 report. This report investigates the level of protection for both front and rear seat occupants involved in side impact crashes and makes a number of recommendations about suitable countermeasures to alleviate these injuries.

1.2 STUDY METHODOLOGY

The project design included a number of different research tasks, including a review of Australian and overseas occupant safety literature, a mass data analysis of the Transport Accident Commission's compensation data base (enhanced with additional information from the Victorian police accident data and the Victorian vehicle performance of these vehicles and which vehicle components are commonly involved in injuries to occupants for a range of different vehicle and crash configurations.

The various tasks and the methods used for each of these components of the research program was described fully in the earlier report (CR95).

This report focuses on the side impact findings of the study, including an overview of vehicle types and components likely to be over-involved in occupant injuries and recommendations for further research and development in improving the level of safety for Australian vehicle occupants in these crashes. A second literature review outlining recent publications in side impact protection is also included which incorporates current developments in side impact regulations both in Europe and North America.

2. SIDE IMPACT LITERATURE REVIEW

Side impacts constitute a large fraction of all injury- producing collisions; 17% to 25% About two-thirds of these are car to car collisions and another 15% to 20% side collisions with poles or trees, a source of high mortality. About half the side collisions are perpendicular and half oblique and 80% involve the passenger compartment (Mackay, 1990).

2.1 SIDE IMPACT CRASHES

According to Marcus, Morgan, Eppinger, Kalieris, Hatten and Schmidt (1983), lateral impacts produce a large proportion of all serious and fatal injuries - as much as 27% to 30% according to Fan (1987). Side impacts account for 12% of total "harm" (Malliaris et al 1982). This proportion would be higher in countries with high belt-wearing rates, as a substantial number of frontal impact casualties would be removed from the total harm. According to Mackay, Parkin, Hill and Munns (1991), of injury-producing collisions with high belt use 20% to 30% are lateral collisions. In Victorian crashes of 1981 and later vehicles for which Transport Accident Commission (TAC) claims were made, side impacts caused 25% of all casualties but 28% of fatalities. Otte (1993) showed the range of directions of impact in two-car side collisions as shown in Figure 2.1.

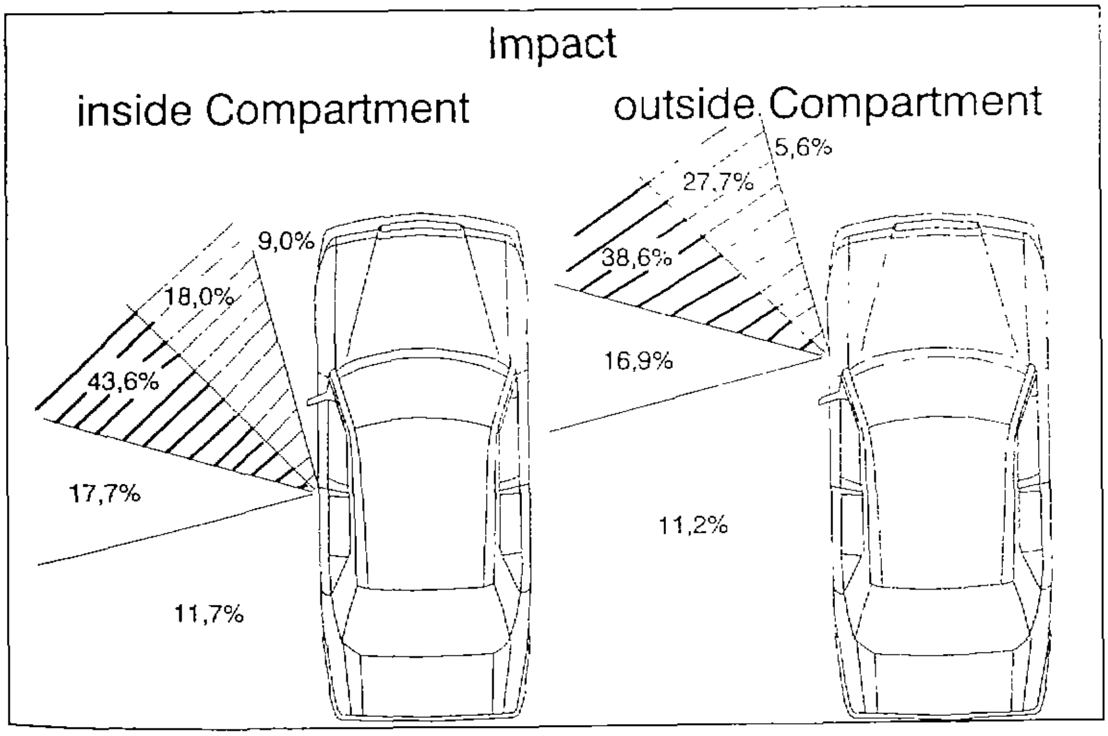


Figure 2.1 Distribution of impact angle (direction of impact of the impacting car) in a range of real-world side collisions (from Otte 1993).

Side impacts present a difficult problem in crash protection as there is little structure between the occupant and the impacting vehicle or object. The front structure of the car can absorb two to five times as much energy as the side structure (Cesari and Bloch 1984).

2.1.1 Injuries From Side Impacts

Head, thorax and pelvis are the main body areas injured and the interior door surface is the most frequent impacting part. Thoracic injury is the highest ranking injury in non-roll-over, non-ejection side impacts (Hackney, Gabler, Kanianthra and Cohen, 1987). From Swedish accidents, Haalund (1991) found that in car-to-car crashes, side impacts gave rise to more severe injuries than frontal impacts. For disabling injuries to be reduced the neck and legs need better protection; as regards life-threatening injuries, chest injuries become up to four times more frequent with advancing age. Injuries were twice as common on the struck as on the opposite side.

When fatalities alone are considered, multiple body regions are frequently injured: Lestina, Gloyns and Rattenbury (1990) found head (64%), chest (85%) and abdomen (26%) predominated in AIS >= 3 injuries in the struck side occupant. On the opposite side the head was most frequently injured (85%) followed by the chest (73%) and abdomen (49%). In both positions , in this series, the occupants had more neck injuries than in the non-fatal series.

Dalmotas (1983) found that, with regard to occupants restrained by seat belts, there was more injury to the shoulder/chest, pelvis and legs among impact-side occupants, whereas there was more injury to the neck, abdomen and arms in far-side occupants. The two groups had similar incidences of head/face injury. The distribution of injuries in this series was very similar to that in Holt and Vazey's 1977 series (pre-ADR 29), shown in Table 2.1.

TABLE 2.1 PERCENT OF 3-POINT BELTED CASUALTIES WITH AIS >= 3 IN SIDE IMPACTS

BODY REGION	HOLT and VASEY	DALMOTAS
Head/face	46.6	48.0
Neck	1.7	7.1
Shoulder/chest	48.3	40.8
Pelvis	24.1	13.3
Abdomen	10.3	11.2
Upper extremities	12.1	14.3
Back	nil	1.0

Source: *Holt and Vazey (1977), Dalmotas (1983). The difference in neck injury frequencies is due to a difference in sampling criteria.*

For head injuries, however, there are a number of contacting parts: the side door rail, window frame, A pillar, B pillar, other interior surfaces and the external impacting object itself as the head rocks through the window space (Willkie and Monk, 1986). A diagrammatic representation of the sources of injury is given by Otte, Suren, Appel and Nehmzow (1984), based on a large sample of side collisions (see Figure 2.2). For drivers involved in side impacts, Otte (1993) demonstrated the maximum deformation height as shown in Figure 2.3.

2.1.2 Injury Mechanisms

Occupants in lateral collisions can be injured by one or more of five main mechanisms (Strother, Smith, James and Warner, 1984):

(a) contacting the (deformed or undeformed) side structure of the occupant's vehilce,

(b) direct contact with the striking object or vehicle,

(c) being contacted by objects (or occupants) from the opposite side of the vehicle.

(d) being compressed between side structures and other parts of the compartment, or

(e) being partially or totally ejected from the subject vehicle.

These authors commented that the fourth mechanism (d) is rare, because collisions with this degree of vehicle crushing causes early fatal impact-type injuries Since the side of the vehicle is usually pushed inward in side impacts, the occupants' injuries were often thought of as being due to crushing Maximum AIS and crush distance were not related in a study of 30 crashes by Huelke, Sherman and Steigmayer (1989).

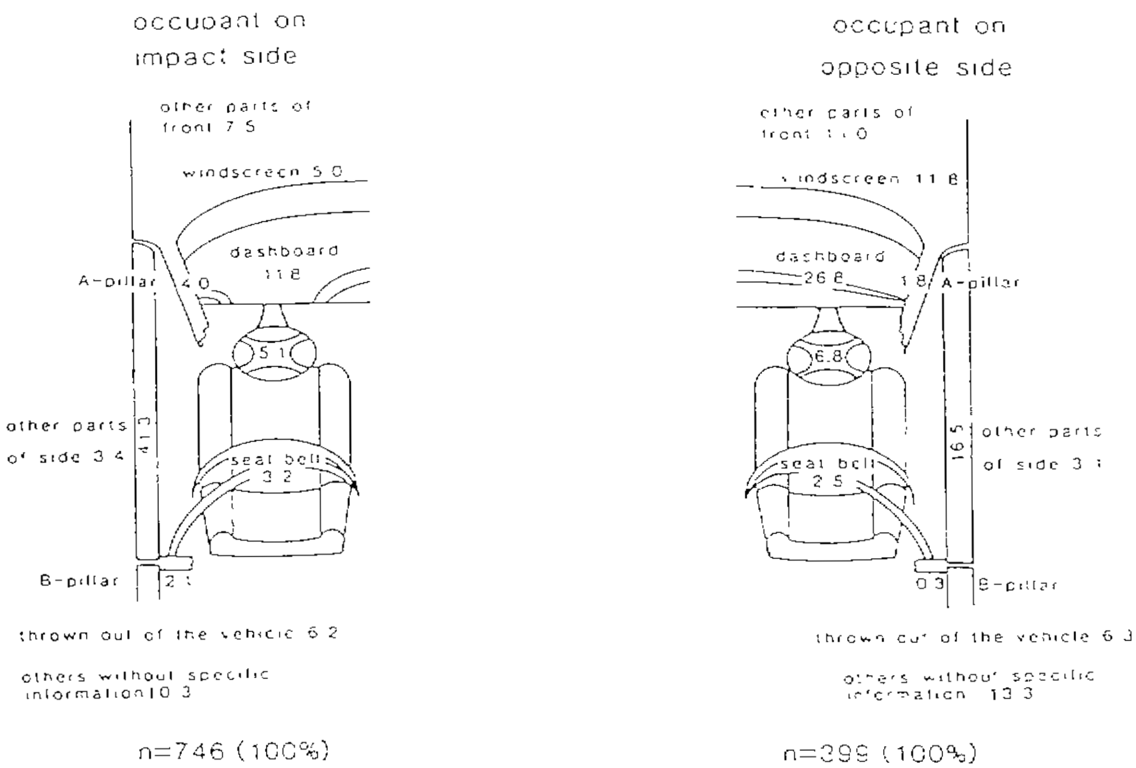


Figure 2.2 Injury-causing parts for laterally impacted passengers, differentiated by seating position (for all injuries 100%) on the impact side and on opposite side (from Otte et al, 1984).

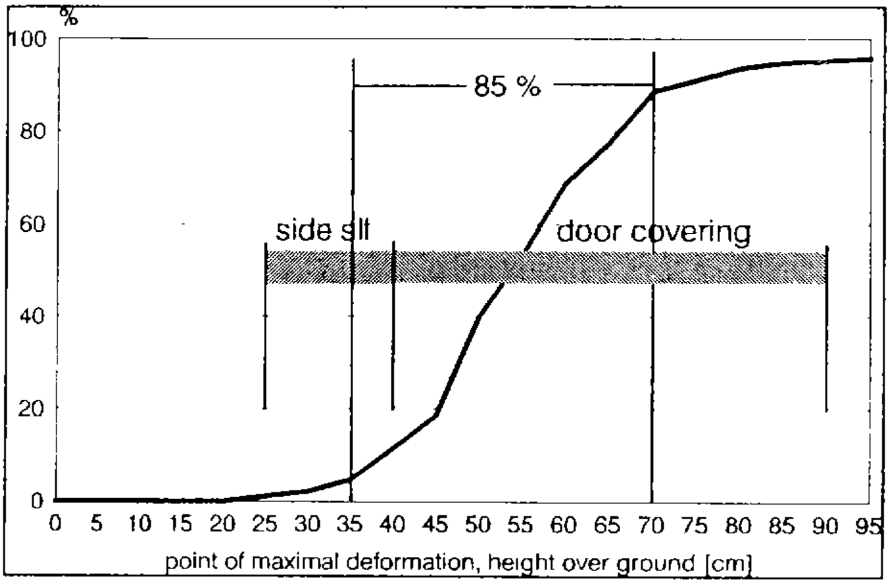


Figure 2.3 Accumulated frequency of maximum deformation height in side collisions based on a sample of representative real-world accident investigations (Otte 1993).

2.1.3 Source of Injury

It is now recognised that the injuries are nearly always impact injuries (Friedel, 1988). The velocity of the side door interior surface on contact with the occupant is similar to the delta-V of the struck vehicle - about 60% of the closing speed of the striking vehicle (Viano, 1987). Lau, Capp and Obermeyer (1991) refer to the critical event as "the stationary occupants being punched by the encroaching door at a high speed with a self-limiting stroke". The overall probability of injury is however not directly related to overall structural stiffness nor to the final extent of the intrusion (Hobbs and Langdon, 1988) Dalmotas (1983), also, recognises that the mechanisms of injury in side impacts are more complex than in frontal collisions.

The events are described by Cesari (1983, p 133 et seq) as follows:

> *"... the occupant sitting on the side of the impact will be struck by the side structure intruding into the passenger compartment while still in his original seating position, and will be accelerated towards the opposite side of the vehicle before the speed of the vehicle itself begins to change to any appreciable extent. In terms of the loading imposed on the occupants, therefore, the motion of the vehicle itself is of merely secondary importance. The decisive factor is actually the large relative motion between the side structure and the vehicle, in other words the rate of intrusion."*

> *"If we consider the case of only one occupant seated in the opposite side injuries are often related to impacts against internal parts of the car, some of them having been deformed by the collision. In the case of two occupants on the same seat row the interaction between them could produce injuries to both of them."*

These interactions between passengers are likely to be important in right angle collisions (Faerber, 1983), the actual consequences depending on whether the interaction takes place after or before the primary impact pulse is finished. Forces between occupants may be one-third of those on the impact-side occupant from the primary impact. Belts may mitigate or even eliminate interactions between occupants (Jones, 1982).

Mackay et al. (1991) found that interaction between front seat occupants was not a frequent cause of injury to the non-struck side occupant, although 35% came out of the sash component of the belt. On the other hand, according to Thomas and Bradford (1989), interaction with a non-struck side occupant appears to aggravate the injuries of 39% of all struck-side occupant fatalities.

Strother et al (1984) analysed the side collision in terms of velocity time diagrams By the time the impact-side occupant has contacted the interior panel, only about one-third of the eventual intrusion has taken place. They argued that the velocity of contact is independent of side stiffness for the first 10 inches (25.4mm) or so of side crush. The far-side occupant (belted or not) may benefit from more intrusion, as the side interior velocity may then be lower when the far-side occupant encounters it. Because of the early (about 25 ms) contact between impact-side occupant and door interior, this occupant may not benefit from break-away utility poles, for the damaging contact will have taken place before the pole separates from its base. This effect was demonstrated, for small cars, in experimental car-pole collisions (Hargrave, Hansen and Hinch, 1989) Post-collision intrusion is a poor and unreliable measure of countermeasures for fixed object lateral collisions (Strother et al, 1984; Dalmotas 1983).

The important factors determining injuries include direction of impacting force, collision severity, mass ratio of striking object and struck car, the response of the car to lateral loading as well as car structural details (Otte et al, 1984; Freidel, 1988).

2.2 EXISTING COUNTERMEASURES

2.2.1 Seat Belts

The three point seat belt should not be overlooked as a countermeasure. It has a substantial protective effect for opposite side occupants; even for impact-side occupants it still has a small effect - for example, reducing the chance of the head swinging through the plane of the window and contacting the striking object (Mackay, 1988). Jones found that impact-side occupants had a risk of injury of 77.9% if unbelted, but 74.5% belted; other-side occupants had 70.3% unbelted and 63.6% belted. When the severity level of the collision is raised and only fatal casualties are considered, belts reduced significantly only head injuries (from 94% to 67%) in opposite-side occupants (Lestina et al, 1990) When the initial trajectory of the occupant could be determined, if its angle with the longitudinal axis of the car was not more than 45 degrees, the three-point belt provided as much protection as in frontal crashes (Schuller, Beier and Steiger, 1989). In National Highway Traffic Safety Administration (NHTSA) tests, Shimoda, Nishida and Akiyama (1989) found that the three-point belt did not prevent the struck-side occupant's head from hitting the upper part of the door or the mobile barrier.

2.2.2 Side Impact Standard ADR29

Door stiffness is the object of the only specific countermeasure so far implemented The countermeasure adopted in Australia, Australian Design Rule (ADR) 29, effective since 1977, follows the USA's Federal Motor Vehicle Safety Standard (FMVSS) 214. It prescribes extra stiffening of the door, measured by static deflection when the door is loaded horizontally by a cylindrical impactor. The requirement is usually satisfied by the addition of a horizontal beam in the door structure, with or without extra strengthening of the door frame

Victorian data were analysed by Cameron (1980), who found that there was no statistically significant evidence to show that compliance with ADR 29 reduced the risk of injury to front seat occupants on the impacted side. Cameron recognised the limitation of the small sample size and that the benefits in a particular type of side impact could be diluted in the broad group of impacts considered.

Kahane (1982) was able to use a large data base, including seven years of Fatal Accident Reporting System (FARS) data, the National Accident Sampling System (NASS) data and three years of Texas accident files to evaluate the effectiveness of FMVSS 214. Kahane found a differential effect: for fatalities; there was no significant effect in car-to-car collisions, but there was a 14% reduction in single-vehicle accidents. If this class is restricted to side impacts with fixed objects, the effectiveness was 23%. For car-to-car collisions, there was a 25% reduction in serious injuries for impact-side occupants. There was, overall, also a reduction of 9% (single vehicle accidents) and 13% (multi-vehicle accidents) in minor injuries.

Regarding vehicle deformation, in single vehicle crashes, the depth of crush decreased on average by 20%, while the width increased by 20%; in multi-vehicle crashes the depth was decreased by 20% while the width was unaffected. Ejection through door openings, incidence of door opening, of latch or hinge damage, of ejection through the door opening and sill override were all reduced in cars complying with FMVSS 214.

The standard added an average of $30 (US, 1982) to the purchase price of the car and had an estimated car-lifetime cost of $61 per car. The standard eliminated 1.7 "*equivalent fatal units*" per million dollars of cost.

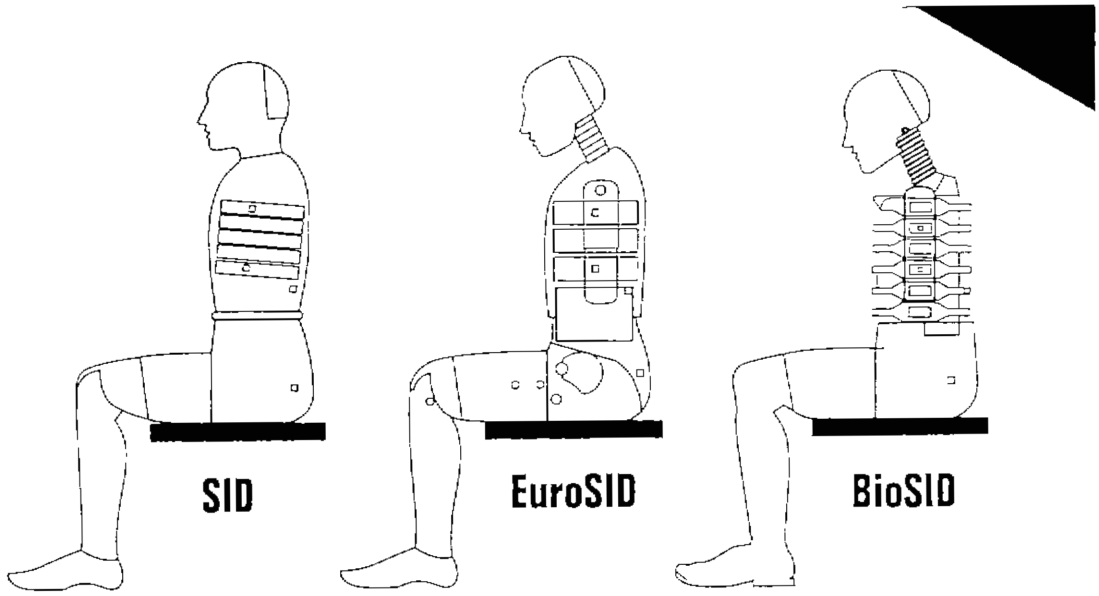
Kahane concluded that the standard helped cars to "*glance by*" fixed objects, limiting the damage in the compartment area and spreading it to less vulnerable regions of the car, but it did not produce deflection of striking vehicles. It reduced the overall severity of the collision not only for the impact-side occupants but also, to a lesser extent, for other occupants. It also helped protect the integrity of the door structure, significantly reducing the risk of ejection. Overall, the benefits were mainly in single vehicle accidents.

2.3 BIOMECHANIC DEVELOPMENTS

During the past two decades, a large amount of research and development has been expended on the side impact problem, primarily in the area of biomechanics. According to Burgett and Brubaker (1982) the side of the vehicle should perform two functions in a crash: prevent ejection and provide a survivable impact environment. The NHTSA side impact program concentrated on thoracic injury measures. The number of fractured ribs is related to the acceleration of the first thoracic vertebra (with age as an intervening variable) and has a curvilinear relation to thoracic AIS. Injury is also related to chest deflection. Force on the abdomen is related, fairly linearly, to its deflection.

Cesari and Ramet (1982) investigated pelvic fractures in side impacts and found that the pubic rami were the most deformed parts. They propose a pelvic human tolerance parameter with 3ms values of 10kN for 50th% male and 4kN for 5th% female. with age, an intervening variable (the threshold for fracture expressed by Acceleration=125-1.1 Occupant's Age). Cavanaugh, Walilko, Malhotra, Zhu and King (1990), found, in cadaver sled tests, that the best predictor of pelvic fracture was maximum velocity, though peak pelvic force and peak compression also performed well. Zhu, Cavanaugh and King (1993) later found "average force" to be a good pelvic injury criterion as it reflects the rate of momentum transfer to the pelvis in side impact (average force is 5kN for a 25% probability of AIS2 injury).

There have been a number of comparisons of dummy responses with cadaver tests and reconstructions of real collisions (early results were summarised by Burgett and Brubaker, 1982). The sub-system approach has been chiefly used for development of, for example, energy-absorbing padding material. The analytical approach requires a mathematical model to reproduce both vehicle and occupant responses with great fidelity. Principal problems have been the need for detailed information on the behaviour of specific body parts. The range of different side impact dummies developed for side impact testing and regulation is shown in Figure 2.4.



*The ribs on these three side impact dummy variations are different The arm configurations are different, too SID (left) doesn't have arms at all Instead, the mass of the chest includes mass approximating that of the shoulders and arms in a "down" position EuroSID (middle) and BioSID (right) have stubby arms. In terms of measuring the likelihood of occupant injury, the differences among the three dummies involve whether they measure acceleration only or acceleration plus compression All three dummies can measure the Thoracic Trauma Index (TTI) an acceleration-based injury criterion EuroSID and BioSID can measure the likelihood of neck and abdomen injury, but SID cannot And EuroSID and BioSID, though not SID, can measure chest compression which, when combined with acceleration measures, allows researchers to calculate the viscous criterion (V*C), a compression-based injury measurement*

Figure 2.4 Crash test dummy development - side impact dummies of the present and future (from IIHS, 1992).

2.3.1 The SID Dummy

Eppinger, Marcus and Morgan (1984) describe the derivation of an index predicting thoracic injury on the AIS scale from 49 cadaver side impacts. The best predictor, according to the authors, is the Thoracic Trauma Index (TTI), defined as:

$$TTI = 1.4\ Age + 0.5\ (T12Y + LURY) \times M/165$$

where age is in years, T12Y is the peak lateral spinal (T12) acceleration, LURY is the peak upper left rib acceleration (ie on side of impact) and M the mass in pounds. Shaibani and Baum (1990) re-analysed the data on which the TTI were based and concluded that it was as good a predictor of injury as any of several alternative models. TTI and pelvic acceleration are used as the criteria, measured on the dummy, in side impact barrier tests in the new FMVSS.

2.3.2 The EUROSID Dummy

A parallel program for development of a dummy (EUROSID), under the auspices of the European Experimental Vehicle Committee has been described by Janssen and Vermissen (1988). The dummy was based on the best features of earlier dummies and the new parts - neck, thorax, abdomen and pelvis - were based on cadaver data. After initial trials and modifications, it was subjected to a program of tests specified by a working group of the International Standards Organisation. While the dummy performed well, it was too stiff, in some tests, which led to higher than specified accelerations. EUROSID is suitable for transducer outputs from which TTI and other indices can be derived.

Comparative evaluation of SID and EUROSID has been described by Bendjellal, Tarriere, Brun-Cassan, Foret-Bruno, Caillibot and Gillet (1988) in terms of head impacts, neck bending, shoulder, thorax and abdomen responses and pelvic performance. Neither dummy complied with all the ISO criteria, but EUROSID does so rather more closely than SID. Irwin, Pricopio, Mertz, Balser and Chkoreff (1989) also found Eurosid to be more “human like” than SID. Eurosid performed well also in comparisons with cadavers in tests by Kallieris, Mattern, McIntosh and Boggasch (1992).

2.3.3 The BIOSID Dummy

The methodology leading to the TTI has not been without critics. Ardoino (1983) and Careine (1991) have questioned the validity of cadaver responses as surrogate for live car occupants. Computer models have been developed for both dummies (for example, Low and Prasad, 1990).

Viano and Lau (1985) noted that cadaver chest compression sufficient to cause injury did not have a fixed maximum, but the critical compression was inversely related to velocity of compression. They argued that chest and abdominal injury was caused by a viscous mechanism during the rapid phase of body compression. This led to the concept of a Viscous Tolerance Criterion, defined as the maximum value of the instantaneous product of compression velocity and percentage compression: $VC = v(t) \times c(t)$ max.

VC has the dimensions of velocity and it is said to be a “measure of energy dissipated by viscous energy in the thorax”. The VC reaches its maximum when body compression has reached only about half its maximum value. The criterion was used initially for analysis of antero-posterior impacts on the thorax and has been extended to the abdomen. From cadaver tests, tolerance values (for 25% probability of serious injury) were established as VC = 1 5 m/s for the chest and 2.0 m/s for the abdomen. These values correspond to 38% and 44% of maximum compression, respectively.

The dummy development program has been criticised by Viano and by others for excessive dependence on skeletal injury and acceleration. Acceleration cannot distinguish between body deformation and translation of the whole body. In their view, SID is an inertia device, not one that relies on a compliant human-like response. An alternative dummy, BIOSID, has been developed based on Viano's biomechanical formulation.

2.4 RECENT REGULATION DEVELOPMENTS

As noted above, the effect of ADR 29/FMVSS 214 was to provide improved protection in side impacts with fixed objects. New technical legislation is directed towards mitigating the effects of car to car side impact.

In addition to the two "*official*" dummies, SID and EUROSID (and BIOSID, developed under the auspices of the Society of Automotive Engineers), there are two test procedures. The U.S. (NHTSA) test (effective in 1993) incorporates a moving barrier with the mass of the median value for U S. cars and a homogenous deformable barrier with a stiffness equivalent to that of a light truck. This impacts the passenger compartment in a crabbed motion at 34 mph (54 km/h). Maximum levels are prescribed for TTI and pelvic acceleration. The proposed European test employs a somewhat "softer" mobile deformable barrier which is supposed to represent the varying stiffness of a real car's front structure The barrier, whose mass is related to the European car fleet, strikes the car perpendicularly at 50 km/h Maximum levels are set for variables related to the head, chest, abdomen and pelvis. Performance in both tests relates to the struck side occupant. The tests differ on 19 of 22 items (Fildes and Vulcan, 1989). It is claimed that differing test elements, dummies and even dummy position (front or rear) can have large effects on the outcome variables in replications of tests on identical 1800 cc Japanese sedans (Campbell, Smith, Wasko and Hensen, 1989).

Lestina et al. (1990), in their study of fatal side impacts, consider that in-car countermeasures would have prevented 11% of the fatalities (struck and non-struck side combined). As noted, Viano suggests that as many as 30% of serious injuries could be prevented by suitably chosen padding. Planath (1992) expects a 25% reduction in injury risk in car-to-car collisions. Less optimistically, Henry, Thomas, Faverjohn, Tarriere, Got and Patel (1989) consider that design changes complying with the U.S. or European tests would save less than 1% of all fatalities and less than 2.5% of all severe injuries (ie 4% of fatalities and 10% of severe injuries in side impacts)

2.4.1 Developments in Side Impact Protection in the USA

The United States has clearly made the running in side impact regulations since the early introduction of FMVSS 214 in mid 1970's which specified a static deflection criterion when the door is loaded horizontally by a cylindrical impactor. This regulation was adopted in Australia in 1977 as ADR 29

In August 1990, they legislated to upgrade FMVSS 214 to include a dynamic side impact test requirement. Manufacturers were given sufficient lead time to meet this requirement which was to be introduced in stages for new vehicles, comprising 10% in 1994 models, 25% in 1995, 40% in 1996, and 100% in 1997 models This means that this year for the first time, a percentage of new US vehicles released in September 1993 will be required to meet this new dynamic side impact regulation.

The US operates a "self-certification" system which expects vehicle manufacturers to comply with the regulations rather than provide test evidence of compliance at time of model release. The National Highway Traffic Safety Administration (NHTSA) periodically purchase (anonymously) particular models and submit them to test for FMVSS requirements. In the event that a vehicle fails to meet a particular requirement (eg: FMVSS 214), a monetary penalty is prescribed for each vehicle manufactured, together with recall procedures to correct faulty components. In practice, if NHTSA's tests reveal a failure, they usually discuss it with the manufacturer and may inspect his records of tests on the same make and model.

It may be that the existence of these procedures lead vehicle manufacturers to adopt statistical based control testing and design tolerance to ensure that each vehicle tested meets the standard. NHTSA believe that the penalty for not meeting a particular standard is sufficient to ensure that most manufacturers will comply.

The National Highway and Traffic Safety Administration (NHTSA) first started research on dynamic side impact testing using cadavers to determine human tolerance levels, injury mechanisms, and parameters for dummy measurement. In addition, accident data was assembled and analysed to develop a moving deformable barrier and crash configuration that simulated a severe side impact crash. These long-term programs eventually lead to the US standard legislated in 1990 for introduction in 1994 passenger cars.

Two aspects of FMVSS 214 seem to have been the subject of most criticism of the US standard. First, the crabbed configuration and the type, size, and stiffness of the barrier have been the subject of much criticism in Europe, although strangely enough not from within the US it seems. The Europeans claim that it does not represent crashes and vehicles more commonly found on the continent and in the UK. Thus, they have proposed an alternative narrower and slightly thicker barrier with variable stiffness honeycomb construction to simulate the varying stiffness of an impacting vehicle and a 90deg pure perpendicular test. They claim that this will lead to stronger more appropriate structures in their vehicle fleet.

More important, though are the claims within the US that the Side Impact Dummy (SID) and the specified injury criteria are not an adequate simulation of human injury (low biofidelity). Lau and Viano (1988) have argued that the use of the Thoracic Trauma Index (TTI) which attempts to predict the probability of injury based on rib and spine accelerations is inappropriate. They maintain from a series of cadaver and animal tests they have conducted that a Viscous Criterion (V^*C) based on the relative displacement of two points on the surface of a struck dummy more accurately represent injury risk. This led to the development of a third side impact dummy, BIOSID, a development by General Motors research laboratories in the US.

This conclusion has also had some support recently by Huang, King and Cavanaugh (1993). Of particular relevance is their finding that soft honeycomb padding which effectively reduced injury to cadavers in side impact tests was predicted well by V^*C but poorly by peak thoracic force (Cavanaugh Zhu, Huang and King 1993). This might suggest that padding which satisfies SID's requirements is not necessarily the best option for occupant protection in side impacts, a claim made by Viano (1991) following tests conducted of the effects of different armrest materials and loadings.

It is understood that Transport Canada is currently undertaking research which compares the US FMVSS 214 and the proposed European test procedure in actual crash tests. It is not clear whether this work also includes relative results of the various dummies We are told that the work by Dalmotas of Transport Canada is almost complete.

NHTSA claim in their final regulatory impact analysis for FMVSS 214 (Eppinger, 1993) that TTI correlates very well with thoracic and abdominal AIS from their cadaver test results. This is to be expected as TTI is the best fit curve from a series of cadaver tests. It would be expected that as FMVSS 214 vehicles come into production and are involved in road crashes, their injury performance relative to similar non-compliant vehicles will be the subject of further research in the US and elsewhere. This will provide the ultimate test of how effective FMVSS 214 has been in mitigating injury in US vehicles.

2.4.2 Developments in Side Impact Protection in Europe

It is claimed that the European side impact procedure that has been talked about over the last few years is now essentially complete. It aims to reduce intrusion and to offer protection to occupants by requiring manufacturers to meet certain side impact crash performance criteria. In this sense, it is similar in nature to the US procedure although it differs substantially in the criteria adopted for crash configuration and moving barrier design. The moving barrier in the European standard is perpendicular rather than crabbed and the barrier surface is thicker but narrower In addition, the dummies are different (EUROSID versus SID) as is the requirement for them to be restrained. Fildes and Vulcan (1989) outlined the full range of differences in side impact requirements between ECE and NHTSA.

We have been advised that the European standard is now essentially complete, that the procedure has been tabled in Geneva, and is set for introduction in Europe from 1 October 1995 using a full scale dynamic test. The final resolution of the regulation and its introduction date will be considered at the March 1994 meeting of WP29 in Geneva. One pessimistic commentator felt that the European standard is still a long way off yet and not likely to be implemented until the year 2000.

2.4.3 Differences Between the Two Side Impact Standards

There are acknowledged technical differences between the two side impact standards, although both are intended to simulate an intersections crash. Another major difference between the two standards is the means by which manufacturers are required by the authorities to prove that their vehicles meet these standards.

As noted above, the US system is one of *"self-certification"* where it is assumed that manufacturers' vehicles meet these standards unless crash testing by NHTSA on a representative production vehicle proves otherwise. Monetary penalties can be prescribed and recall action mandated if non-compliance is discovered The Europeans, on the other hand, administer a "type approval" system where a vehicle model is certified by the authorities prior to it being allowed on the market This involves prototype testing, witnessed by the approval authority. The various vehicle safety regulations that apply are all done this way and an "E" mark is issued for each regulation for complying vehicles. Whole vehicle approval is the responsibility of each country using the presence of the various "E" marks applying to that model as proof of compliance to all ECE regulations One of the conditions of issuing an "E" mark is that all subsequent production vehicles continue to meet these regulations. Manufacturers must have a system in place to ensure that this is the case.

A view expressed by TRL personnel was that the US system was likely to be a more critical (thorough) system than the European one. First, it was argued that the US approach was likely to ensure a slightly higher degree of intrusion protection, given the very nature of the approach (manufacturers would need to build in some added strength to ensure a particular test vehicle was unlikely to fail). Second, the fact that at any time, NHTSA could undertake a test and then request the manufacturer's own data if there was a failure was felt to be a better system of ensuring on-going quality control of intrusion protection.

The Australian certification system is more akin to the European system in that test evidence is required to demonstrate compliance prior to gaining approval to market a vehicle model. FORS conduct audit of the tests facilities to ensure that the certification tests have been carried out by experienced personnel with correct equipment. FORS also conduct audits of manufacturing facilities to ensure that quality systems are in place to ensure production vehicles meet the ADR's. Areas of non-compliance can be addressed with the recall provisions of the Trade Practices Act. These variations ensure that many of the criticisms that were levelled against the European system do not apply in Australia.

All three systems are aimed at ensuring that production vehicles meet the requirements. As a result, many manufacturers design to a higher level that the legislative requirement to ensure a level of statistical confidence above that that might apply to a production vehicle on any one particular test.

2.4.4 Vehicle Manufacturers Reaction

Japanese and European car manufacturers expect to have to comply with both standards when selling their vehicles to both the European and North American markets. It is not clear whether they will make separate cars for each market or simply ensure their vehicles meet both tests, although the latter would seem more likely. These manufacturers are not particularly keen on the proposed European standard, especially since FMVSS 214 is now in place. They obviously feel it is too costly to have to meet both standards in terms of having to crash their vehicles. Some manufacturers are actively promoting the quasi-static *"Composite Test Procedure"* (CTP) as an alternative to crash testing cars where they would develop models from car tests that could be used to demonstrate satisfactory performance in a component test rig. The sceptical view was that the CTP was purely a delaying tactic.

2.4.5 CTP Test Program

The European regulators have apparently taken the position of agreeing to a CTP providing it produces similar results to the proposed full test procedure. To this end, there is a program of research under way in Europe to compare results from both. This has both manufacturing (ACER) and government backing by TRL (UK), BAST (Germany), TNO (Holland), UTAC (France), and INTER (Spain). ECE are partially funding the research (presumably with manufacturers support) and UTAC in France are co-ordinating the exercise.

The first phase of the program involved 3 crashes (with comparison CTP tests) and were scheduled to be completed by September 1993. If successful, a further 6 full crash tests were to be conducted over the course of 1994.

It is felt that either way, this test program will not interfere with the introduction date of 1 October 1995 for the full scale test procedure. To the regulators, CTP has always been seen as an alternative means of demonstrating compliance, rather than a stand alone requirement. As noted above, the final resolution of the side impact regulation for Europe will be considered at the March 1994 meeting of WP29 in Geneva.

2.4.6 Australian Situation

The current situation in Australia is that apart from the Holden Commodore and the Ford Falcon, all other passenger cars sold in this country are also available in Europe and/or the USA. It is generally agreed world-wide that a dynamic side impact test requirement will provide additional tangible reductions in road trauma beyond any existing standard (such as ADR 29) or no standard at all. Thus, it would seem reasonable to consider the benefits of developing ADR 29 to include a dynamic performance test.

One approach would be to allow Australian vehicles to comply with either the USA or European standard. Advice from FORS suggests that the local industry might be willing to accept such an approach However, whether this will provide adequate protection beyond the current ADR 29 still needs to be assessed and will be discussed in more detail below.

2.5 COST-EFFECTIVENESS OF SIDE IMPACT STANDARDS

None of the people consulted were aware of any research either conducted in the past, current, or proposed into the likely cost-effectiveness of the European proposal. They noted that the US regulators had included a statement of likely benefits when they put out their notice of rulemaking but believed that the Europeans were less inclined to undertake a similar exercise. A paper by Henry, Thomas, Faverjohn, Tarriere, Got and Patel (1989) claimed that the benefits would save 4 percent of all fatalities and 10 percent serious injuries in side impact crashes, although it is difficult to place much reliance on these figures without a detailed appreciation of the standard proposed for Europe.

2.5.1 FMVSS 214 Costs and Benefits

The National Highway Traffic Safety Administration have undertaken a detailed analysis of the likely benefits to be achieved by FMVSS 214 and expected vehicle and test costs. The analysis is detailed and complex and stops short of providing a Benefit-Cost-Ratio

BENEFITS: NHTSA estimate the benefits to be gained by the introduction of the regulation in the US for projected 1995 accidents as:

- 567 lives saved and 2,113 AIS 3-5 non-fatal injuries, assuming some far-side and non-compartment benefits and 100% fleet compliance, or
- 390 lives saved and 1,519 AIS 3-5 non-fatal injuries, assuming that there are no far-side benefits and no benefit from non-compartment strikes.

As stated earlier, much of the basis for these benefit calculations is based on the biofidelity of SID and the criteria specified for manufacturers to meet. Much of the response from the manufacturers to these estimates claim that the benefits are over-estimated because of NHTSA's assumed effectiveness range and the type of padding dictated by TTI. Without real world comparative crash results, it is impossible to determine whether NHTSA's benefits are likely to be realised from the introduction of FMVSS 214.

COSTS: In terms of costs, Tables are provided of likely total costs, broken down by type of vehicle and front and rear seat occupant and including lifetime fuel cost penalties. They claim that the cost analysis is presented for "*illustrative purposes only and is not intended to be used to estimate a per vehicle cost.*" They do not make estimates of marginal costs for particular manufacturers and of operating expenses, claiming that there is no single formula for allocating the various operating expenses including profit over a particular vehicle line on a per vehicle basis. This seems to be more a problem for the US than Australia.

2.5.2 Australian Costs and Benefits

What the likely costs and benefits would be for introducing a side impact standard in Australia at this time is extremely difficult to determine. First, there is little consensus about what the likely benefits would be for either FMVSS 214 (which is at least documented) and the ECE proposal (which is still not publicly available). Second, it is not clear what design changes would be required on Australian vehicles to meet these standards. Finally, even assuming that the US experience directly translates to Australia, it would require an extremely detailed exercise at least as extensive as that undertaken in CR100 to arrive at a unit cost per vehicle that would be accurate and meaningful. However, it should be stressed that there is considerable agreement world-wide that a dynamic test requirement is likely to produce tangible reductions in road trauma

2.6 VEHICLE DESIGN FACTORS

The relevant engineering features of a vehicle that are available for manipulation are the door stiffness, vehicle structure, energy-absorptive padding and the spacing between occupant and interior door surface. The conceptual solution is considered by Daniel (1989) to be along these lines;

- reduce the door-to-occupant velocity to the extent practicable by innovative door, door-beam, door frame and other side structure design,
- use the door inner space to the extent practicable so that the visible "pad" can be reasonably soft and not [so] excessively thick to reduce package space and cramp the occupants or force the design of a wider vehicle,
- use visco-elastic energy absorbing material to the extent practicable that replicates the body's ability to tolerate loading (ie; more compliant for low velocity impacts and less compliant for higher ones), and/or
- less efficiently, use a constant stiffness material (semi-triangular in load-deflection pulse shape).

Rouhana and Kroell (1989) note that discontinuity's in the door inner surface can cause significant injuries - cut-outs (map pockets} are as important as protuberances (arm rests) as potential contributors to injury.

2.6.1 Side Impact Padding

Numerous estimates have been made of the influence of spacing, padding and door stiffness, using mathematical simulations with or without experimental validation. Generally, both padding and stiffness have been considered in combination. Viano (1987) found that the crush force needed to reduce peak biomechanical response varied with impact velocity. Deng (1988) found, with simulations, that padding would reduce occupant acceleration but would increase body deformation, indicating that padding needs to be accompanied by other design changes such as increased stiffness. Deng (1989) later showed the importance of test method. "*free flight*", ie, pendulum tests, were inappropriate for sub-system tests of padding materials.

Brubaker and Tommassoni (1983) found that padding alone did not improve the thorax response, but was beneficial to the pelvis Segal (1983), on the basis of trials with two computer models, found that door interior padding was beneficial across a range of body sizes. Computer modelling to evaluate the effect of design parameters has been described by Trella, Gabler, Kanianthra and Wagner (1991) and the TTI was mapped in terms of different levels of struck car stiffness and padding. Other simulation models were reviewed by Langdon who concluded that then current models (1989) did not provide a complete substitute for full scale impact tests.

In car-to-car oblique crashes simulated by Tommassoni (1984) most benefit came from padding to make use of the door interior, but extra stiffness was of some benefit. With regard to stiffness alone, Strother et al (1984) considered an increase would only be of value if it moderated the contact surface velocity. A study of car body lateral impact characteristics in right angle impacts at moderately high speed (12.5 m/s, 45 km/h) suggested that stiffer door structures might actually increase dummy acceleration, but foam padding might decrease thorax and pelvic acceleration by 10%. The main conclusion of Hardy and Suthurst (1985) was the importance of compatibility between parts in modifying the vehicle's structure.

The relative effects of design factors were investigated by Preuss and Wasko (1987) through side impacts tests on 16 identical cars modified to give two levels of spacing, padding and stiffness The significant variables were found to be padding and stiffness which reduced the dummy response by 30 and 7 TTI units respectively, compared with a standard deviation of 5 6 TTI units. (Typical TTIs in sideways tests range between 100 and 150 TTI units.) According to the test analyses, the two variables can be evaluated separately The study has been criticised by Lau, and Viano (1988) chiefly on the grounds that the SID dummy exaggerates the effect of padding.

Cavanaugh, Zhu, Huang and King (1993) argued that the human thorax is exquisitely sensitive to the stiffness of the padding in side impact contacts. NHTSA conducted impact tests on 28 modified production cars (Gabler, Hackney & Hollowell, 1989) and found a variable they called DEPTH (door effective padding thickness) to be highly correlated with occupant protection as measured by TTI. DEPTH is, in effect, the amount the occupant crushes the door. DEPTH is, in turn, correlated with external door crush at axle height

The practical thickness of energy-absorbing padding is an important variable. Lane width is determined by the dimensions of the largest vehicles (trucks and buses) and parking bays by large cars. It may be possible to bulge the sides of small and medium cars in the passenger area, without alteration of track or occupant position, so that a modest increase in car body width could provide a substantial proportionate in space available for padding Consideration of this possibility had not been encountered in the literature reviewed.

2.6.2 Side Airbag

A side airbag has been proposed to take the place of padding in the chest region. A bag could make valuable use of the space between occupant and interior surface to provide "*ride-down*", for this is space that cannot, practically, be used for energy-absorbing padding (Olsson Skotte and Svendsson, 1989, Warner, Strother, James, Stuble and Egbert, 1989). According to Olsson et al., an eight litre bag would reduce the TTI by 27%, and head ejection by 80mm. Haland and Pipkorn (1991) showed that, in a side impact, an 8 litre chest air bag, which behaves like "soft thick padding", gave lower head, neck and chest loading than 50mm of chest padding. They also reported that 75 mm of padding opposite the pelvis reduced pelvic loads. According to these authors, with padding and an air bag, both the U.S. and European standards could be met.

A larger, 40 litre, air bag deploying from the armrest and extending when inflated to the roof side rail, has been described by Kiuchi, Ogata, Warner and Gordon (1991). This bag should reduce head injury, but the possibility of injury to the outboard arm of the driver needs further investigation.

The property of head contact surfaces in side impacts is a special case of contact with interior surfaces generally. (It should be noted that the amended FMVSS does not specify a figure-of-merit for head impacts in the side impact test procedure). Willkie and Monk (1986) investigated the stiffness of narrow surfaces, pillars and roof rails, by impacts with a rigid head-form at 15 mph. A number of car models were used as test specimens. They were able to express the Head Injury Criterion (HIC) in terms of surface stiffness: HIC = 0.508 x k + 100, where k is the stiffness in lb/in. Attempts to develop a relation with the Mean Strain Criterion were less successful.

It appears that many factors, regardless of the mathematical or physical model used, interact to influence the effect of spacing, padding thickness and density, and door stiffness on the probability of injury to an impact-side occupant. In these circumstances, there can scarcely be an optimum mix of door design factors across all impacts.

From a consideration of the distributions of injury and speed in real world crashes. Viano (1987) suggests that reductions of up to 30% in seriously injured occupants may be possible with a low stiffness energy absorbing material that is effective in low-speed (deltaV=4-8 m/s) crashes. Low or high stiffness padding was ineffective in high-speed crashes (deltaV>10 m/s).

2.6.3 Side Impact Protection

Volvo Car Corporation recently developed and introduced into their new passenger car design a Side Impact Protection System (SIPS) to offer occupants improved protection in side impact crashes. The SIPS design aims to limit the degree of intrusion of the side wall on the struck side and to keep the speed of this intrusion to a low level. It achieves this by installing cross members under the rear seat and the front seat to help spread the load. In addition, the B-pillar is strengthened, along with upgrading the roof rail and strengthening the roof cross member. Lateral tubes were placed under the seat or in the seat to transfer the crash energy onto the energy-absorbing box mounted on the tunnel between the two front seats. A schematic view of the SIPS design is shown in Figure 2.5.

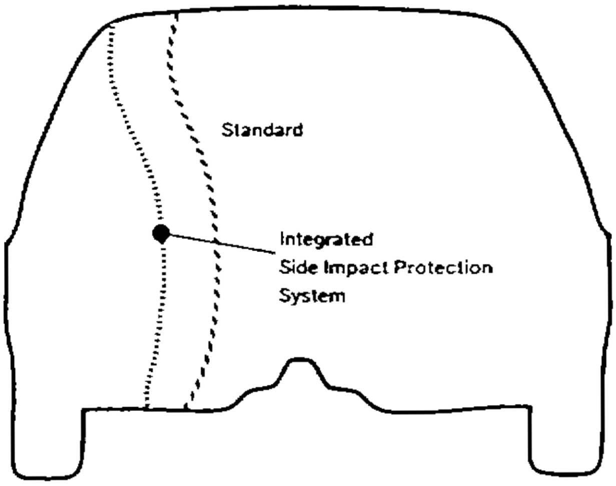


Figure 2.5 Volvo's scheme for limiting side impact intrusion (from Planath 1993).

It is not totally clear how effective the SIPS system is at providing increased occupant protection in side impacts. From internal testing by Volvo, Planath (1993) claimed that SIPS would reduce the risk of pelvic and severe to fatal chest injuries in these collisions (presumably on the near-side) by 25%. Moreover, she argued that this reduction might be even greater if very large blocks of padding could be mounted on the door panel, although she recognised that this could interfere with compartment roominess and occupant comfort. It will be interesting to see whether these claims of SIPS effectiveness hold when sufficient real-world crash data is collected to permit relative assessments.

2.7 SUMMARY OF SIDE IMPACT REVIEW

In summary, a substantial though not spectacular reduction of injuries in side collisions would seem possible through car design, although there are still a number of unresolved issues. Much information has been collected but there are still areas of disagreement between experts on the critical variables or their derivatives to be used for predicting injury. There are two well-developed but different anthropomorphic test dummies and different impact test procedures. Some concern has been expressed about reliance on a single test for demonstrating compliance with whatever standard is adopted.

The responsible authorities in the U.S.A and Europe have decided on two different test procedures and dummies, that cannot be harmonised, but which are not necessarily incompatible for compliance purposes. It would be feasible to arrive at estimated benefits and possibly costs for implementing a side impact standard similar to either the US or proposed European standards. However, the available data on the likely injury savings and the costs of how manufacturers would meet these standards is a little unclear at this stage. Given that a dynamic standard is likely to reduce side impact trauma in road crashes, there is clearly a need for further investigations on the advantages of Australia adopting either or both standards before the year 2000.

3. CRASHED VEHICLE STUDY

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

3.1 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 where at least one of the vehicle's occupants were either hospitalised or killed. As the study was primarily concerned with secondary safety aspects of the vehicle's crashworthiness performance, in-depth analysis at-the-scene was not attempted. The method was outlined previously in the earlier frontal crash study report (Fildes, Lane, Lenard and Vulcan 1991) and is included here again for completeness.

3.1.1 The Vehicle & Occupant 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 in Victoria where at least one occupant was injured severely enough to require admission to (or treatment in) hospital. The breakdown of the sample revealed 3% of the patients required medical treatment only, 82% were admitted for at least one night, while 15% died either at the scene or later in hospital (details of cases where occupants died at-the-scene were kindly provided by the Coroner's office). Previous reports had demonstrated that the cases collected in this study using this strategy were roughly representative of all serious injury cases in Victoria (Monash University Accident Research Centre 1992).

3.1.2 Procedure

The process was triggered by the admission of a suitable road crash victim at one of a number of Melbourne and Metropolitan 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. For cases where the patient was severely injured, permission was sought from a member of the patient's family.

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.

3.1.3 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). This value 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 and are subject to some error from the assumptions and vehicle stiffness values used in making these calculations. In this study, American stiffness values had to be used in the calculations of delta-V for vehicles of the same sizes as the Australian vehicles as local figures were not readily available. These errors could be reduced to some degree if appropriate stiffness values for Australian vehicles were to be provided by the local manufacturers.

3.1.4 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: It is difficult interpreting occupant protection effects for vehicles involved in multiple collisions (ie when impacted by more than one vehicle or object, often in different crash configurations). This is because of the problems that arise in determining which impact caused which injury from which contact source. Thus, only single collisions were considered eligible here, although the impacted object could have been either another car, a truck, or a movable or immovable object including roll-overs.

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. As noted earlier, details of fatalities where the patient died at the scene were kindly provided directly by the Coroner's Office in Melbourne.

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.

3.1.5 Hospital Participation Rates

Approval to approach and interview patients was obtained from the ethics committees of ***five*** major trauma hospitals in Victoria and included the Alfred Hospital (and Trauma Centre), Box Hill Hospital, Dandenong and District Hospital, Monash Medical Centre, and the Austin Hospital (Spinal Unit). In addition, another ***three*** private hospitals to whom road trauma patients from Dandenong were transferred, namely Knox Private, Dandenong Valley Private, and South Eastern District Hospitals, also kindly agreed to participate. This approval was subject to obtaining the patient's agreement to participate, as well as ensuring confidentiality of this information.

On average, 100 patients were admitted each week across the five study hospitals requiring treatment from vehicle 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). A reducing road toll over this period meant that more cases were available at the start than at the end, of the study.

3.1.6 Patient & Vehicle Assessment

The assessment and classification of injuries sustained by road trauma patients (including injury severity judgements) requires specialised medical training and skills. Four State Registered Nurses (SRN's) were employed by MUARC during the course of this study 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 1989). A hospital pro forma was developed to provide a standardised format for the collection of the patient's medical, vehicle, and crash information which was trialed 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 were 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 Kenerely Digges, and Mr. Tom Gibson).

The National Highway Traffic & Safety Administration (NHTSA) in Washington D.C. kindly provided the National Accident Sampling System's (NASS) crash inspection pro forma (including training and coding manuals) as well as the computer software CRASH3 for computing Delta-V (see Attachment 3). Figure 3.1 shows the NASS vehicle pro forma 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.

3.1.7 Coding Injuries & Contacts

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 a number of discrete body regions to simplify the analysis and yet still permit meaningful comparisons to be made.

For side impacts, there were ***seven*** body region injury categories assigned for analysis, namely the head, face, chest, abdomen and pelvis, spine, upper extremity, and lower extremity.

INJURY CONTACT SOURCES: 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 a limited number of meaningful categories.

For side impacts, there were **eighteen** vehicle regions, comprising the front windscreen and header, steering assembly, instrument panel, console, A, B and C pillars, roof, roof side rail, door panel, side windows, floor and toe pan, rear windscreen and header, seats, seat belts, other occupants, exterior contacts, and other/unknown. Some of these categories were expanded further when analysing by near and far side crashes. Steering assembly included the steering wheel and column, floor and toe pan included the pedals in the front, while the instrument panel comprised both upper and lower sections.

A further aspect of the injury which was coded was whether it was *direct* (caused by direct contact with a specific vehicle component) or *indirect* (resulting from injury to another impacted body region). Examples of indirect injury include:

- transient loss of consciousness from severe chest injuries caused by contact with the door panel;
- abdominal/pelvic injuries caused by relayed forces from the lower limbs contacting the steering assembly or instrument panel.

3.2 VARIABLES & ANALYSES OF THESE DATA

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 the restraint 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 & 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.

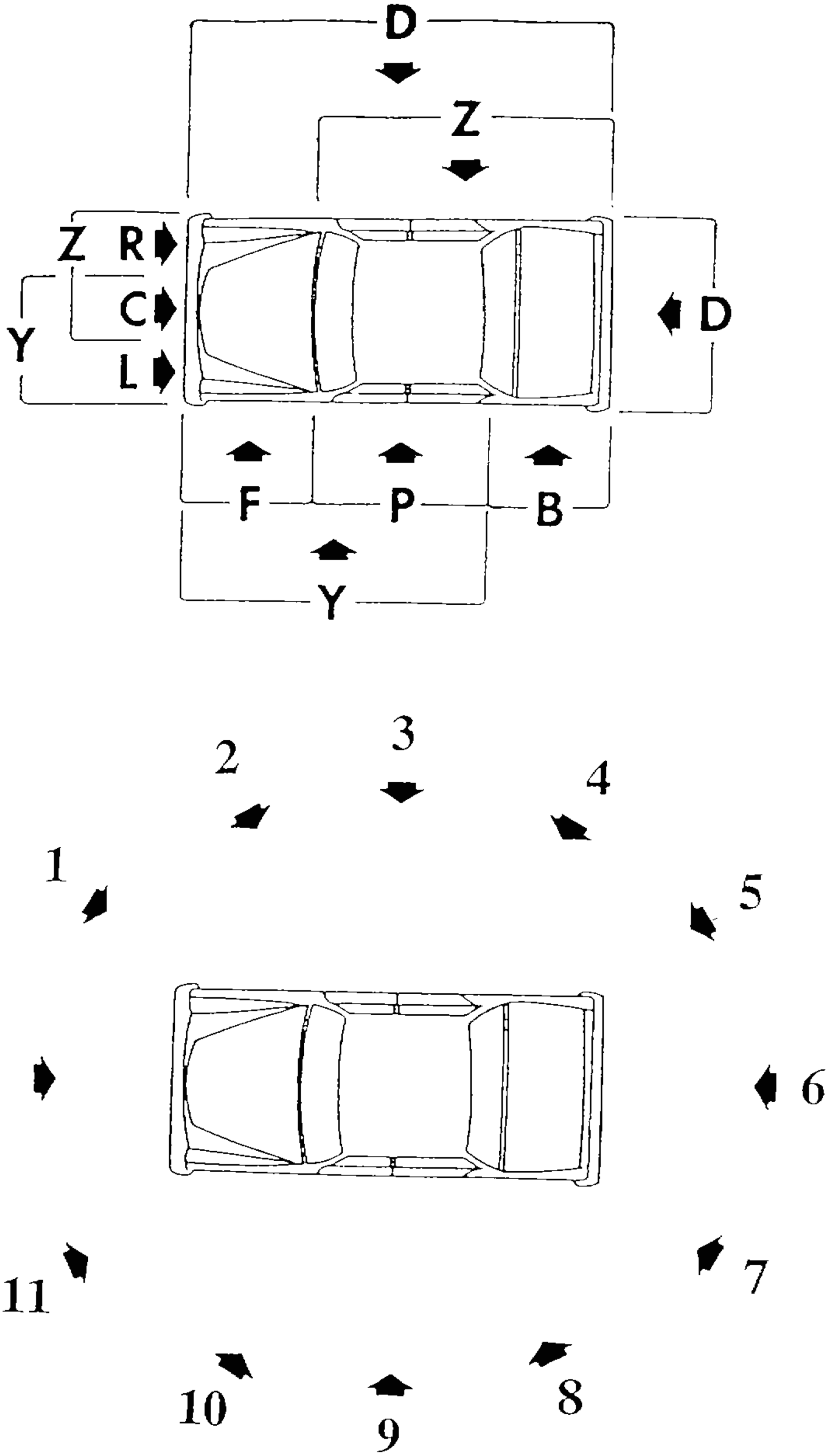


Figure 3.1 National Accident Sampling System pro forma for coding vehicle impact location and direction.

3.2.1 Overall Results

The final data base comprised details on 501 vehicles involving 606 patients from crashes that occurred in Victoria between the 1st April 1989 and the 31st July 1992, comprising 69% metropolitan and 31% rural crashes. The crashed vehicle database contains information on 572 variables for each crash investigated.

Analysis of the crash configurations on the data base showed that frontal crashes accounted for 56% of all crashed vehicles inspected, side impact 41%, roll-overs 3%, and there were no rear-end collisions included in the sample. While the proportion of frontal collisions was slightly less to that reported among TAC claims for the same period (56% cf 65%, Fildes et al 1991), there were differences in the proportions of side impact (41% cf 14%), rear end (0% cf. 11%), and roll-overs (3% cf. 10%). Given the focus of this report, the analysis to follow will concentrate entirely on results of side impact collisions (readers interested in frontal crashes should refer to the earlier report by Fildes et al 1991).

TABLE 3.1 POPULATION CHARACTERISTICS OF THE SIDE IMPACT CRASHES IN THE CRASHED VEHICLE FILE (N=198 crashes)

1. IMPACT VELOCITY	
Mean Delta-V	35.3 km/h
Standard Deviation	15.6 km/h
Range	8-113 km/h
2. VEHICLE TYPES	
Mini	4%
Small	28%
Compact	44%
Intermediates	23%
Large	1%
Mean vehicle weight	1086 kg
3. SEATING POSITION	
Driver	60%
Front-left	27%
Rear	13%
Near-side occupants	70%
Far-side occupants	30%
4. PATIENT SEX	
Males	48%
Females	52%
5. PATIENT AGE	
< 17 years	5%
17 - 25 years	26%
26 - 55 years	44%
56 - 75 years	19%
> 75 years	6%

3.3 SIDE IMPACT CRASHES

Details were available on 198 side impact crashes involving 234 injured occupants. The population characteristics of the side impact sample are shown in Table 3.1. These findings are described below. Fildes et al (1991) reported that side impacts were involved in 14% of TAC injury claims from 1983 until 1988, yet they accounted for 41% of the patient population observed here.

This clearly illustrates how relatively severe these crashes are compared to other crash configurations and the greater likelihood of serious injury to occupants involved in side impact collisions.

3.3.1 Impact Velocity

The mean estimated delta-V value was 35.3km/h with a standard deviation of 15.6km/h. Figure 3.2 shows the distribution of impact velocity change observed in the sample of side impact crashes. The modal value was between 25 and 30km/h with a range of impact speeds from 8 to 113km/h.

Eighty nine percent of side impact delta-Vs were equal to or below 54 km/h, while 36% were equal to or below 27 km/h, the approximate value for the US design standard for side impacts FMVSS 214, corresponding to a perpendicular impact velocity of 48km/h (54km/h for a 27deg crabbed configuration) and two vehicles of equal mass

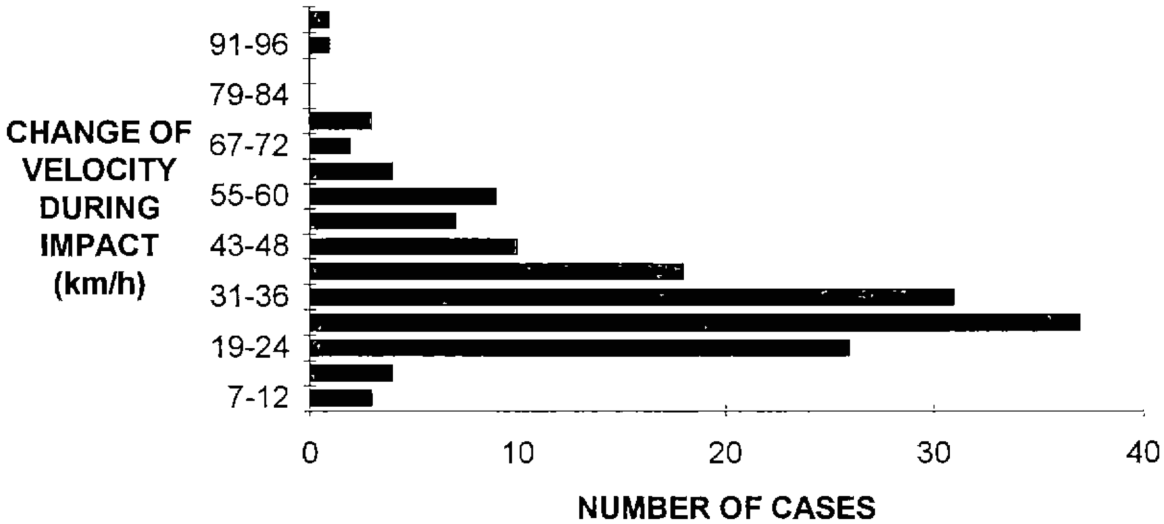


Figure 3.2 Frequency histogram of side impact velocity change (delta-V) observed in the sample of 198 side impacted vehicles.

3.3.2 Type of Vehicle

Four percent of the crashed vehicles were mini-cars (<750kg), 28% were small (<1000kg), 44% compacts (1001-1250kg), 23% intermediates (1251-1500kg), and 1% large cars (>1500kg). Table 3.2 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 nor their relative exposure to gauge relative involvement rates. Forty four percent of the vehicles had manual transmissions while the rest were automatics. Front-wheel-drive transmission was observed in 45% of the vehicles, rear-wheel drive in 52% and four-wheel drive in 3%.

Most occupants admitted to hospital were seated in bucket seats (84%). Seat failures occurred in 26% 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 equally as likely to fail in side impact crashes.

3.3.3 Patient Characteristics

Sixty percent of patients were drivers, 27% were front-left seat occupants, while 13% were rear seat occupants. The sample comprises 48% males and 52% females which is roughly equivalent to population ratios. Five percent of the patients were aged under 17 years, 26% were between 17 and 25 years, 44% were 26 to 55 years old, 19% were 56 to 75 years, and 6% were over 75 years.

In contrast to the frontal crash findings, those aged 17 to 25 years were not markedly over-represented as patients in side impact collisions, compared with both population and license holder proportions in Victoria. However, those aged over 75 years were two times over-represented compared to population figures showing a greater likelihood of injury to these people due to their frailty if involved in a crash.

Sixty two percent of the injured occupants were seated on the *Near side* of the vehicle (on the same side as that impacted) and 38% were on the *Far side* (opposite side of the car). This findings was expected for an injured population in that those seated near the impacted region are much more likely to be injured than those seated further away. However, the fact that roughly one-third far side occupants are still being injured in these collisions is somewhat alarming.

3.3.4 Seatbelt Wearing

Eighty four percent of all injured occupants wore seat belts at the time of their collision. This varied from 88% for drivers, 86% for front-left passengers, and 54% 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).However, the lower wearing rate observed among the injured occupants in this study (87% cf. 94% in the front and 54% cf 66% in the rear) demonstrates again that seat belts reduce serious injuries to vehicle occupants even in side impact crashes (it may also reflect a tendency for those not wearing belts to be more involved in side impact crashes).

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 of the belt having been loaded during the crash.

3.3.5 Configuration of Side Impacts

The impacted region for passenger cars involved in side collisions were analysed in terms of the impact zone relative to the passenger compartment and angle of impact and the results are

TABLE 3.2 LIST OF THE TYPE OF SIDE IMPACT VEHICLES ON THE CRASHED VEHICLE FILE (n=198)

VEHICLE MAKE/MODEL	NUMBER	PERCENT	MASS
Holden Commodore/Calais	30	15.2	1215-1367kg
Ford Falcon/Fairmont	21	10.7	1333-2190kg
Ford Laser/Meteor/Mazda 323	18	9.1	820-995kg
Toyota Corolla	13	6.6	910-970kg
Mitsubishi Sigma	10	5.1	1095-1250kg
Toyota Corona/Camry/Apollo	10	5.1	1060-1150kg
Nissan Pulsar/Holden Astra	9	4.6	890-936kg
Mazda 626/Ford Telstar	9	4.6	1003-1155kg
Holden Camira	8	4.1	1021-1122kg
Nissan Pintara	7	3.6	1150-1287kg
Nissan Bluebird	6	3.0	1080-1200kg
Holden Barina	5	2.5	710kg
Mitsubishi Magna	4	2.0	1193-1265kg
Toyota Celica	4	2.0	1150-1165kg
Nissan Skyline	3	1.5	1215-1250kg
Daihatsu Charade	3	1.5	675-710kg
Honda Prelude	3	1.5	985-995kg
Subaru DL 18	3	1 5	1075-1080kg
Mitsubishi Colt	2	1.0	911-940kg
Honda Civic	2	1.0	825-920kg
Mazda 929	2	1.0	1135-1280kg
Mitsubishi Cordia	2	1.0	1000-1030kg
Hyundai Excel	2	1 0	950kg
Suzuki Hatch	2	1.0	680-730kg
Suzuki Alto	2	1.0	550-700kg
Suzuki Swift	2	1.0	790kg
Mazda RX7	2	1.0	1095kg
Nissan Stanza	2	1.0	955-960kg
Rover 416i	1	0.5	1055kg
Alfa Alfetta	1	0.5	1140kg
Honda Accord	1	0.5	977-992kg
Subaru GL5	1	0.5	970kg
Subaru Liberty	1	0 5	1147kg
Subaru TWA	1	0.5	1105kg
BMW 318i	1	0.5	1425kg
Nissan Gazelle	1	0.5	1100-1120kg
Porsche 944	1	0.5	1180kg
Saab 900	1	0.5	1185-1315kg
Ford LTD	1	0.5	1697kg

Note: *A summary of each of these cases is available in the supplementary volume to this report (F.O.R.S. Report No. CR 134A).*

shown in Figure 3.3. Pure compartment impacts were defined as those where the bullet vehicle impacted only the cabin (section P on the NASS diagram described in Figure 3.1), 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). The results in Figure 3.2 show that the passenger compartment was fully or partially impacted in 90 percent of side impacts where occupants were injured and that impact direction was evenly divided between perpendicular and oblique impacts.

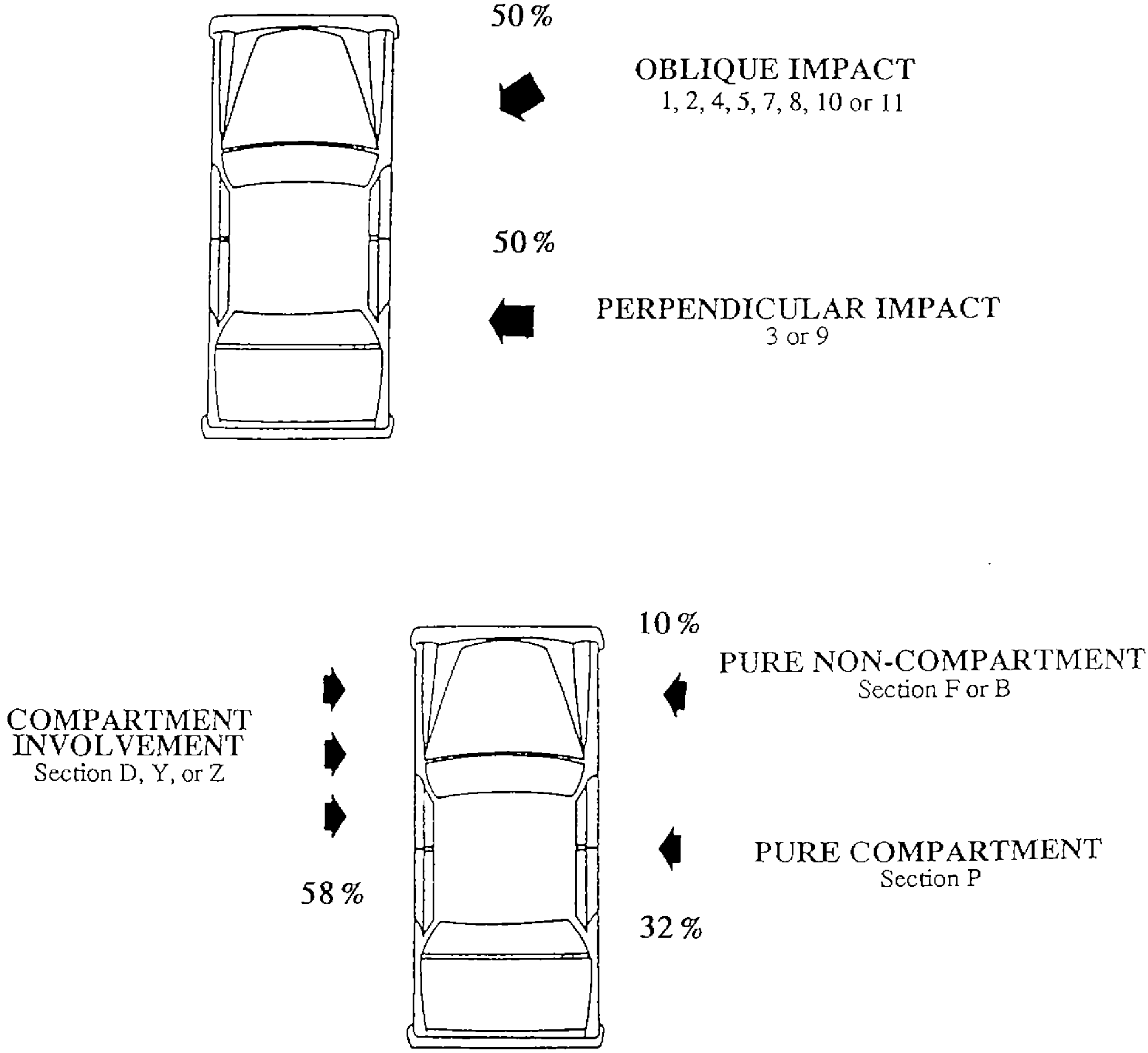


Figure 3.3 Analysis of the various side impacted regions of the vehicles observed in the sample of crashed vehicles inspected to date.

3.3.6 Intrusions and Deformations

Table 3.3 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 (3.0 cf. 1.5 intrusions per side crash). It should be borne in mind, however, that this is partly a function of the lack of exposure of rear seat occupants in vehicles and the fact that someone had to be injured for the vehicle to have been included in the study.

TABLE 3.3 RANK ORDERING OF VEHICLE DAMAGE INTRUSIONS AND DEFORMATIONS FROM SIDE IMPACTS BY FRONT AND REAR SEATING POSITIONS (198 vehicles)

FRONT SEAT DEFORMATION			REAR SEAT DEFORMATION		
ITEM	FREQ	(%)	ITEM	FREQ	(%)
Door panel	177	(89%)	Door panel	150	(76%)
B-pillar	119	(60%)	B-pillar	31	(16%)
A-pillar	90	(45%)	Roof	29	(15%)
Side panel	61	(31%)	Roof side rail	25	(13%)
Steering assy	58	(30%)	C-pillar	22	(11%)
Roof side rail	39	(20%)	Front seat	12	(6%)
Roof	28	(14%)	Side panel	10	(5%)
Toe pan	23	(12%)	R'screen/header	2	(1%)
Instrument panel	17	(9%)	Floor pan	1	(1%)
W'screen/header	8	(4%)	A-pillar	1	(1%)
Front seat	6	(3%)	Window frame	1	(1%)
Console	6	(3%)	Rear seat	1	(1%)
Floor pan	2	(1%)	Other	6	(3%)
Window frame	1	(1%)			
Other	3	(2%)			
Totals	**584**	**(295%)**		**291**	**(147%)**

STEERING ASSY MOVEMENTS BY DIRECTION OF DISPLACEMENT

Lateral	58	(29%)
Longitudinal	17	(9%)
Vertical	39	(20%)

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.

For both front and rear seat intrusions, the door panel was the most common area of deformation or intrusion, occurring in 89% and 76% of all crashes, respectively. B-pillar (60%) and A-pillar (45%) were the next most frequent intrusion mechanism in the front seat, followed by the side panel (31%), steering assembly (30%), roof side rail (20%), roof (14%) and toe pan (12%). After the door panel, the most frequent rear seat intrusions comprised the B-pillar (16%), roof (15%), roof side rail (13%) and the C-pillar (11%). Steering assembly intrusions were again quite apparent in these crashes (30%). Displacement direction was more often lateral (29%) or vertical (20%), rather than longitudinal (9%).

3.3.7 Ejections and Entrapments

The number of occupants entrapped in their vehicles during side impact crashes is shown in Tables 3.4. There were fewer entrapment cases for non-wearers of seat belts than for wearers (14% cf. 39%). Ejection rates, shown in Table 3.5 were as expected; belt wearers had fewer ejections than non-wearers (2% cf. 38%). However, while ejections were high among non-wearers as expected (38%), there were a few cases also among belted occupants (2%). Clearly, there are still some cases (albeit only minimal) where current seat belt designs fail to prevent ejections in side impact collisions.

TABLE 3.4 ENTRAPMENT ANALYSIS FOR BELTED AND UNBELTED OCCUPANTS INVOLVED IN SIDE IMPACT CRASHES (n=234 patients)

ENTRAPMENTS	BELTED		UNBELTED	
	FREQ	(%)	FREQ	(%)
No entrapment	82	(61%)	25	(86%)
Full entrapment	8	(6%)	1	(3%)
Partial entrapment	44	(33%)	3	(11%)
Total	**134**	**(100%)**	**29**	**(100%)**

NB: The total number of cases of entrapment and no entrapment falls far short of the total number of patients (163 cf 234) due to the difficulty in assigning entrapment status retrospectively.

TABLE 3.5 EJECTION ANALYSIS FOR BELTED AND UNBELTED OCCUPANTS INVOLVED IN SIDE IMPACT CRASHES (n=234 patients)

EJECTIONS	BELTED		UNBELTED	
	FREQ	(%)	FREQ	(%)
No ejection	172	(98%)	21	(62%)
Occupant ejected	4	(2%)	13	(38%)
Total	**176**	**(100%)**	**34**	**(100%)**

NB: Ejections were difficult to determine using follow-up procedures. Where ambulance and medical records or eye witness accounts noted that the occupant had been fully or partially ejected from the vehicle during the crash and remained that way post-crash, these were coded as ejections. Cases where parts of the occupant may have been transiently thrown out of the vehicle during the crash sequence but subsequently came to rest inside the vehicle were treated as non-ejected in this analysis.

3.4 INJURIES IN SIDE IMPACT CRASHES

The study was especially interested in the types of injuries and their sources of injury inside the vehicle. In addition, analysing the injury and contact source combinations provides a means of identifying particular components inside the vehicle that are a major causes of injury to occupants in these crashes requiring intervention effort.

3.4.1 Body Regions Injured

Table 3.6 shows that drivers sustained marginally more injuries on average than other occupants (5.0 cf. 4.9 for FLP and 4.6 for rear). However, there was practically no difference in injury severity across the various seating positions either in terms of the average Injury Severity Score (ISS) or the probability of serious injury by ISS or AIS level. Of particular note, however, the average ISS was considerably higher for side impacts than front impacts (30 4 cf 17.2) and the proportion of killed to hospitalised occupants was also markedly higher for side collisions (21% cf. 11%) illustrating just how severe occupant injuries are in this crash configuration.

For all injuries to ***drivers***, the most frequent body regions injured for all collisions were the head (70%), abdomen and pelvis (70%), and upper extremity (67%). For severe injuries (AIS>2) to drivers, the most frequent body regions injured were the chest (29%), head (26%), abdomen and pelvis (16%) and lower limbs (12%).

For ***front-left passengers***, the most frequent body regions injured were the chest (77%), abdomen and pelvis (76%), and the head (65%), while for severe injuries, the order included the chest (39%), head (24%), abdomen and pelvis (18%), and spine and neck (15%).

For ***rear seat passengers***, the most frequent body regions injured comprised the upper extremities (68%), face (65%), chest (58%), and head (52%), while for severe injuries only, the most frequent body region injured were the chest (32%), abdomen and pelvis (19%), and upper extremity (16%) and the head (13%). There were practically no severe injuries to the face, lower limbs or spine or neck in this rear seating position.

In addition, Table 3.7 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. As noted above, there were very few discernible differences either in the average Injury Severity Score (ISS) or the probability of severe injury suggesting that there is no seating position that is particularly safe for vehicle occupants involved in side impact collisions.

3.4.2 Sources of Injury

Table 3.8 shows that the outstanding source of injury for ***drivers*** in side impacts was the door panel (71% of total and 28% severe injuries). Beyond that, seat belts (35%) and the instrument panel (34%) were also prominent contact points in this crash configuration. While exterior contacts were involved in 23% of total occupant injuries, they were a particularly noteworthy source of severe injury to drivers (11%).

This pattern was also fairly consistent for ***front-left passengers*** and ***rear seat passengers***. However, in the rear, there was a relative increase in the number of exterior and window and frame contacts, probably because of the higher non-wearing rates of seat belts in this seating position. The front left passenger was also disproportionately involved in severe injury from contact with other occupants, but this, too, may simply reflect the fact that these people always have another occupant (the driver) to contact, whereas drivers and rear seat passengers are less likely to have other occupants to contact in these crashes.

Seat belts are thought to be primarily a frontal crash countermeasure, although the results obtained here suggest that they may still have some protective benefit in side crashes as well, as noted earlier in the literature review. Of some concern, though, is the amount of injury caused by the seat belt in these lateral crashes, although, as seen in Table 3.9, these injuries do tend to be minor ones.

TABLE 3.6 BODY REGION INJURED FOR ALL COLLISIONS

BODY REGION INJURED	DRIVERS(n=141) ALL (AIS>2)	FRONT LEFT(n=62) ALL (AIS>2)	REAR(n=31) ALL (AIS>2)
Head	70% (26%)	65% (24%)	52% (13%)
Face	60% (1%)	48% (0%)	65% (0%)
Chest	67% (29%)	77% (39%)	58% (32%)
Abdomen & pelvis	70% (16%)	76% (18%)	48% (19%)
Upper extremity	67% (5%)	47% (3%)	68% (16%)
Lower extremity	54% (12%)	48% (6%)	45% (3%)
Spine & neck	26% (4%)	26% (15%)	32% (3%)
Average/Patient	**5.0 (1.9)**	**4.9 (2.0)**	**4.6 (1.8)**

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

TABLE 3.7 SEATING POSITION BY LEVEL AND PROBABILITY OF A SERIOUS INJURY

SEATING POSITION	OCCUPANTS	AV. ISS*	PROBABILITY OF SERIOUS INJURY AIS>2	ISS>15	ISS>25
Driver	141	29.6	0.76	0.70	0.48
Front-left	62	30.1	0.77	0.69	0.35
Rear	31	34.5	0.74	0.61	0.42
Total (Averages)	**234**	**(30.4)**	**(0.76)**	**(0.69)**	**(0.44)**

* *Injury Severity Score (ISS) is a generally accepted measure of overall severity of injury from road trauma (Baker et al 1974). It is calculated by summing the squares of the 3 highest Abbreviated Injury Scores (AIS) recorded for each of 3 body regions injured.*

TABLE 3.8 POINTS OF CONTACT FOR ALL SIDE IMPACT COLLISIONS

POINTS OF CONTACT	DRIVERS(n=141) ALL (AIS>2)	FLP(n=62) ALL (AIS>2)	REAR(n=31) ALL (AIS>2)
Front screen & header	2% (1%)	3% (0%)	0% (0%)
Steering assembly	14% (4%)	2% (0%)	0% (0%)
Instrument panel	34% (4%)	26% (2%)	3% (3%)
Console	6% (1%)	3% (0%)	0% (0%)
Window & frame	19% (1%)	23% (0%)	22% (3%)
A-pillars	5% (1%)	6% (2%)	0% (0%)
B-pillar	6% (3%)	15% (0%)	3% (0%)
C-pillar	1% (0%)	0% (0%)	3% (0%)
Roof side rail	1% (0%)	2% (0%)	3% (3%)
Roof surface	6% (4%)	2% (0%)	3% (3%)
Door panel	71% (28%)	84% (34%)	55% (23%)
Floor & toe pan	11% (2%)	8% (3%)	3% (0%)
Rear screen & header	1% (0%)	0% (0%)	3% (0%)
Seats	3% (0%)	3% (0%)	10% (0%)
Seat belts	35% (3%)	35% (3%)	16% (0%)
Other occupants	10% (3%)	16% (11%)	3% (3%)
Exterior contacts	23% (11%)	24% (10%)	39% (3%)
Other/unknown	38% (1%)	31% (10%)	26% (0%)
Average/Patient	**3.8 (1.7)**	**3.8 (1.7)**	**2.9 (1.4)**

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

3.4.3 Injuries by Seating Position

The injury by source of injury analysis for side impact crashes by seating position is presented in Tables 3.9 to 3.17. Multiple scoring of injuries and points of contact for each occupant was allowed, providing they were unique injury-source combinations, to ensure all noteworthy injuries and contact sources were included. Results of the injury/source analyses will be reported by the three main seating positions (drivers, front-left passengers and rear-seat passengers) and by restraint use (belted and unbelted).

DRIVERS: Table 3.9 shows that for all injuries to drivers, the most frequent body regions injured in side impacts were the upper extremities, abdomen-pelvis, chest, head, and lower limbs, while for severe injuries (AIS>2), the most frequent body regions injured were the chest, head, abdomen-pelvis, and lower limbs. The most common contact point was the door panel, although the seat belts, exterior objects, the instrument panel, and side windows were also noteworthy. The most common injury/source contacts for drivers in side impacts were:

- chest with door panel (45%),
- abdomen-pelvis with door panel (41%),
- lower limbs with instrument panel (28%),
- upper extremity with door panel (28%), and
- abdomen-pelvis with seat belt (25%).

TABLE 3.9 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO THE 141 DRIVERS IN SIDE IMPACT COLLISIONS.

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header	1	1					1 (1)	3 (1)
Steering assembly		1	6 (4)	2 (1)	6	2	1 (1)	18 (6)
Instrument panel	2 (2)	6	1		8 (1)	28 (5)	1	45 (8)
Console				1	1 (1)	4		6 (1)
A-pillar	3 (1)	1				2 (1)	1	7 (2)
B-pillar	3 (3)	1	1 (1)		4			9 (4)
C-pillar	1				1		1	3 (0)
Roof side rail	1	1					1 (1)	3 (1)
Roof	5 (3)	4	1		1		1 (1)	12 (4)
Door panel	4 (2)	1	45 (32)	41 (12)	28 (3)	20 (7)	9	148 (56)
Side windows	10 (1)	10			8			28 (1)
Floor & toe pan						11 (2)		11 (2)
Rear screen & header	1							1 (0)
Seat	1		1				1	3 (0)
Seat belt	2 (1)	1	17	25 (3)	8	1	3	57 (4)
Other occupants	4 (2)	2 (1)	7 (4)	4 (1)	6 (1)	3		25 (9)
Exterior	18 (13)	11 (1)	2 (1)	3 (2)	9 (2)	5 (1)	4	52 (20)
Indirect	12			2 (1)			1	15 (1)
Other/unknown	14 (4)	16	2 (1)	6	18	1	6 (1)	63 (6)
TOTAL	82 (32)	55 (2)	83 (43)	84 (20)	97 (8)	77 (16)	31 (5)	509 (126)

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

TABLE 3.10 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO THE 122 *RESTRAINED* DRIVERS IN SIDE IMPACTS

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header		2						2
								(0)
Steering assembly		2	7	2	7	2	1	21
			(3)	(1)			(1)	(5)
Instrument panel	2	6			9	30	1	48
	(2)				(1)	(5)		(8)
Console				2	1	5		8
					(1)			(1)
A-pillar	2	1				2	1	6
						(1)		(1)
B-pillar	2	1			4			7
	(2)							(2)
C-pillar	1				1		1	3
								(0)
Roof side rail		1					1	2
								(0)
Roof	6	5	1		2		2	16
	(3)						(1)	(4)
Door panel	13	1	43	40	27	20	9	153
	(1)		(28)	(9)	(2)	(6)		(46)
Side windows	10	10			8			28
	(1)							(1)
Floor & toe pan						11		11
						(2)		(2)
Rear screen & header	1							1
								(0)
Seat	2		1				2	5
								(0)
Seat belt	2	1	20	28	9	2	3	55
				(3)				(3)
Other occupants	5	2	8	6	5	3		28
	(2)	(1)	(4)	(1)	(1)			(9)
Exterior	17	9	2	2	7	2	1	40
	(11)	(1)	(1)	(1)	(2)			16
Indirect	3			2			1	6
				(1)				1
Other/unknown	13	16	2	5	17	1	6	60
	(2)		(1)				(1)	(4)
TOTAL	79	57	84	86	97	78	29	510
	(24)	(2)	(37)	(16)	(7)	(14)	(3)	(103)

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

TABLE 3.11 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO THE 17 *UNRESTRAINED* DRIVERS IN SIDE IMPACTS.

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header	6						6	12
							(3)	(3)
Steering assembly			6					6
			(3)					(3)
Instrument panel			6	6		12		24
								(0)
Console								0
								(0)
A-pillar	6							6
	(3)							(3)
B-pillar	12		6					18
	(6)		(3)					(9)
C-pillar								0
								(0)
Roof side rail	6						6	12
							(3)	(3)
Roof								0
								(0)
Door panel	12	6	47	41	29	12	12	159
	(6)		(13)	(10)	(3)	(6)		(38)
Side windows	12	12			6			30
								(0)
Floor & toe pan						6		6
						(3)		(3)
Rear screen & header								0
								(0)
Seat								0
								(0)
Seat belt	6	6		6				18
								(0)
Other occupants								0
								(0)
Exterior	29	24	6	12	24	24	24	143
	(10)			(6)		(3)		19
Indirect	6							6
								(0)
Other/unknown	12	12			18			42
								(0)
TOTAL	107	60	71	65	77	54	48	482
	(26)	(0)	(19)	(16)	(3)	(12)	(6)	(81)

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

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

- chest with door panel (32%),
- head with exterior object (13%),
- abdomen-pelvis with door panel (12%),
- lower limb with door panel (7%), and
- lower limb with instrument panel (5%).

Restrained Drivers: Given the disproportionate number of belt wearers and non-wearers among this injured population, it was necessary to examine the injury patterns by restraint use separately. Table 3.10 shows the injury by source analysis for the 141 restrained drivers. The pattern of injuries, points of contact, and injuries by contacts for both all injuries and severe injuries (AIS>2) was the same to that already reported above for all drivers. Drivers sustained 5.1 injury-source contacts per injured occupant.

Unrestrained Drivers: There were differences in injury patterns, however, for unrestrained drivers, shown in Table 3.11, where they sustained on average 4.8 injury-source contacts. The head was the most commonly injured body region for these occupants (107%), followed by upper extremities, chest, abdomen-pelvis, and the face. For severe injuries (AIS>2), the order comprised the head, chest, abdomen-pelvis, and lower limbs. Points of contact for these injuries were mainly the door panel and exterior objects, reflecting a greater tendency for these occupants to be ejected. The most noteworthy of all injury by contact source interactions were:

- chest with door panel (47%),
- abdomen-pelvis with door panel (41%),
- head with exterior objects (29%),
- upper extremity with door panel (29%),
- face with exterior object (24%), and
- upper extremity with exterior object (24%).

while for severe injuries, these comprised:

- chest with door panel (13%),
- head with exterior object (10%),
- abdomen-pelvis with door panel (10%),
- head with door panel (6%), and
- abdomen-pelvis with exterior object (6%).

FRONT-LEFT PASSENGERS: Table 3.12 shows the injuries and points of contact inside the vehicle for 62 front-left passengers involved in side impacts. The most frequent body regions injured were the chest, abdomen-pelvis, head, and lower limbs while for severe injuries only (AIS>2) these included the chest, head, abdomen-pelvis, and lower limbs. Once more, the door panel was, by far, the most common point of contact for both all and severe injuries, along with external objects, seat belts, instrument panel, windows and other occupants. The 5 most noteworthy all injury/source contacts were:

- chest with door panel (63%),
- abdomen-pelvis with the door panel (61%),
- lower limbs with door panel (27%),
- lower limbs with instrument panel (26%), and
- upper extremity with door panel (21%).

For severe injuries only, these included:

- chest with door panel (37%),
- abdomen-pelvis with door panel (21%),
- head with exterior object (13%), and
- chest with other occupant (11%).

Restrained FLP: As with the finding for drivers, the injury patterns for the 51 restrained front-left passengers shown in Table 3.13 were similar to those for all front-left passengers, apart from a slightly higher tendency for relatively more seat belt contacts, notably involving relatively minor chest injuries. Restrained front-left passengers on average sustained 4.9 injury-source contacts per injured occupant.

Unrestrained FLP: Table 3.14 on unrestrained front-left passengers, on the other hand, shows that these occupants experienced 7.4 injury-source contacts per injured occupant and their injury patterns were quite different to their restrained counterparts. Lower limb injuries predominated, followed by upper extremity, head, chest and abdomen-pelvis. Severe injuries (AIS>2) involved the lower limbs, chest, head and neck-spine. Again, the door and exterior objects were principally associated with most of these injuries (exterior objects actually were the most frequent source of severe injury for FLP). The four most common injury-source contacts were:

- chest with door panel (50%),
- abdomen-pelvis with door panel (50%),
- head with exterior object (50%), and
- lower limbs with instrument panel (50%).

For severe injuries (AIS>2), the most common injury-source combinations were:

- chest with door panel (25%),
- head with exterior object (25%),
- abdomen-pelvis with door panel (25%),
- lower limbs with instrument panel (25%), and
- chest with exterior object (25%)

REAR SEAT PASSENGERS: Table 3.15 shows the number of injuries (all and severe) and points of contact for the 31 rear seat passengers involved in side collisions. The most frequent body regions injured for these occupants included the upper extremities, face, lower limbs, chest and head, while severe (AIS>2) injuries occurred in the chest, abdomen-pelvis, upper extremities, and the head. The most notable points of contact were exterior objects, the door panel, and side windows, while the most noteworthy injury/source contacts were:

TABLE 3.12 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO THE 62 FRONT-LEFT PASSENGERS IN SIDE IMPACTS.

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header	3 (2)	2			2			7 (2)
Steering assembly					2			2 (0)
Instrument panel		2	2 (2)	3	2	26 (3)	2 (2)	37 (7)
Console						3		3 (0)
A-pillar	2				2	3 (2)	2 (2)	9 (4)
B-pillar	6 (2)	3	2		10			21 (2)
C-pillar								0 (0)
Roof side rail		2						2 (0)
Roof		2						2 (0)
Door panel		2	63 (37)	61 (21)	21 (2)	27 (5)	4	178 (66)
Side windows	11 (3)	16	2		6		2	37 (3)
Floor & toe pan						8 (3)		8 (3)
Rear screen & header								0 (0)
Seat						3		3 (0)
Seat belt	3 (2)	2	23	18 (2)	6			51 (4)
Other occupants	3 (3)	5	13 (11)	3 (2)	3	3		30 (16)
Exterior	19 (13)	16	5 (3)	5	8	3 (2)	5 (5)	62 23
Indirect	13 (2)						2	15 2
Other/unknown	18 (8)	2		2	13 (2)	2	8 (3)	45 (13)
TOTAL	78 (36)	54 (0)	110 (53)	92 (25)	74 (4)	78 (15)	26 (12)	512 (144)

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

TABLE 3.13 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO THE 51 *RESTRAINED* FRONT-LEFT PASSENGERS IN SIDE IMPACTS

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header	2							2 (0)
Steering assembly								0 (0)
Instrument panel		2				24		26 (0)
Console						4		4 (0)
A-pillar	2					2	2 (2)	6 (2)
B-pillar	8 (2)	4	2		12			26 (2)
C-pillar								0 (0)
Roof side rail		2						2 (0)
Roof		2						2 (0)
Door panel			67 (39)	65 (22)	18 (2)	25 (4)	4	179 (67)
Side windows	12 (4)	16			8		2	38 (4)
Floor & toe pan						6		6 (0)
Rear screen & header								0 (0)
Seat						2		2 (0)
Seat belt	4 (2)	2	25	20 (2)	6			57 (4)
Other occupants	4 (4)	4	16 (14)	4 (2)	4	4		36 (20)
Exterior	16 (12)	16	2	4	4	2	6 (4)	50 16
Indirect	14 (2)						2	16 2
Other/unknown	16 (8)			2	12 (2)	2	6 (2)	38 (12)
TOTAL	78 (34)	48 (0)	112 (63)	95 (26)	64 (4)	71 (4)	22 (8)	490 (129)

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

TABLE 3.14 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO THE 8 *UNRESTRAINED* FRONT-LEFT PASSENGERS IN SIDE IMPACTS.

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header	13 (13)	13			13			39 (13)
Steering assembly					13			13 (0)
Instrument panel			13 (13)	25	13	50 (25)	13 (13)	114 (51)
Console								0 (0)
A-pillar					13	13 (13)		26 (13)
B-pillar								0 (0)
C-pillar								0 (0)
Roof side rail								0 (0)
Roof								0 (0)
Door panel		13	50 (25)	50 (25)	25	38 (13)	13	189 (63)
Side windows	13	25	13					51 (0)
Floor & toe pan						25 (25)		25 (25)
Rear screen & header								0 (0)
Seat						13		13 (0)
Seat belt								0 (0)
Other occupants								0 (0)
Exterior	50 (25)	25	25 (25)	13	38	13 (13)	13 (13)	177 (76)
Indirect	13							13 (0)
Other/unknown	25 (13)	13			13		25 (13)	77 (26)
TOTAL	114 (51)	89 (0)	101 (63)	88 (25)	128 (0)	152 (89)	65 (39)	737 (267)

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

- chest with door panel (32%),
- abdomen-pelvis with door panel (29%),
- upper extremity with exterior objects (29%),
- upper extremity with door panel (26%), and
- head, face, and lower limbs with exterior objects (26%).

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

- chest with door panel (23%),
- upper extremity with exterior objects (13%),
- abdomen-pelvis with exterior object (10%),
- abdomen-pelvis with door panel (6%), and
- chest with exterior object (6%).

Restrained Rear: Results for the 13 restrained rear seat passengers are shown in Table 3.16. On average, they sustained 3.3 injury-source contacts per injured occupant. Their most frequent injuries included the upper extremity, head, lower limb, chest, and face, while for severe injuries only (AIS>2), these included the chest, upper extremities, and the head. Common points of contact were the door, exterior objects, and side windows generally with the seat belt prominent among minor injuries. Notable injury-source contacts included:

- chest with door panel (38%),
- upper extremity with door panel (38%),
- abdomen-pelvis with door panel (31%),
- head with exterior objects (23%), and
- head and face with side windows (23%).

and for severe injuries, these were:

- chest with door panel (23%),
- upper extremity with exterior objects (15%),
- upper extremity with door panel (8%), and
- head with side windows and exterior objects (8%).

Unrestrained rear: Injury patterns for the 11 unrestrained rear occupants are shown in Table 3.17 where they sustained on average 6.1 injury-source contacts per injured occupant. Their most frequent injuries were to the face, upper extremities, lower limbs, and the chest, while these included the chest, abdomen-pelvis, lower limbs, and the head for severe (AIS>2) injuries. The most common source of injury for these unrestrained rear seat occupants was exterior objects followed by the door panel for both minor and major injuries. Notable injury-source contacts included:

- face, chest, upper ext. and lower limbs with exterior objects (55%), and
- abdomen-pelvis and neck-spine with exterior objects (45%).

TABLE 3.15 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO THE 31 REAR SEAT PASSENGERS IN SIDE IMPACT.

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header								0
								(0)
Steering assembly								0
								(0)
Instrument panel					3	3		6
						(3)		(3)
Console								0
								(0)
A-pillar								0
								(0)
B-pillar		3				3		6
						(3)		(3)
C-pillar		3						3
								(0)
Roof side rail	3						3	6
	(3)						(3)	(6)
Roof	3							3
	(3)							(3)
Door panel		6	32	29	26	10	3	106
			(23)	(6)	(3)	(3)		(35)
Side windows	10	19			3			32
	(3)							(3)
Floor & toe pan						3		3
								(0)
Rear screen & header		3					3	6
								(0)
Seat		3				6		9
								(0)
Seat belt			6		10			16
								(0)
Other occupants			3	3				6
			(3)	(3)				(6)
Exterior	26	26	19	16	29	26	16	158
	(3)		(6)	(10)	(13)			(32)
Other/unknown	13	10			10	13		46
	(3)							(3)
TOTAL	55	73	60	48	81	64	25	406
	(15)	(0)	(32)	(19)	(16)	(9)	(3)	(94)

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

TABLE 3.16 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO THE 13 *RESTRAINED* REAR SEAT PASSENGERS IN SIDE IMPACTS

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header								0 (0)
Steering assembly								0 (0)
Instrument panel								0 (0)
Console								0 (0)
A-pillar								0 (0)
B-pillar								0 (0)
C-pillar								0 (0)
Roof side rail								0 (0)
Roof								0 (0)
Door panel			38 (23)	31	38 (8)	8	8	123 (31)
Side windows	23 (8)	23			8			54 (8)
Floor & toe pan								0 (0)
Rear screen & header								0 (0)
Seat						15		15 (0)
Seat belt			8		23			31 (0)
Other occupants								0 (0)
Exterior	23 (8)	8			15 (15)	15		61 (23)
Other/unknown	15	15			8	8		46 (0)
TOTAL	61 (16)	46 (0)	46 (23)	31 (0)	92 (23)	46 (0)	8 (0)	330 (62)

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

TABLE 3.17 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO THE 11 *UNRESTRAINED* REAR SEAT PASSENGERS IN SIDE IMPACTS.

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header								0
								(0)
Steering assembly								0
								(0)
Instrument panel					9	9		18
						(9)		(9)
Console								0
								(0)
A-pillar								0
								(0)
B-pillar		9				9		18
						(9)		(9)
C-pillar		9						9
								(0)
Roof side rail	9						9	18
	(9)						(9)	(18)
Roof	9							9
	(9)							(9)
Door panel		9	27	27	27	18		108
			(18)			(9)		(27)
Side windows		18						18
								(0)
Floor & toe pan						9		9
								(0)
Rear screen & header		9					9	18
								(0)
Seat								0
								(0)
Seat belt								0
								(0)
Other occupants								0
								(0)
Exterior	36	55	55	45	55	55	45	346
			(18)	(27)	(9)			(54)
Other/unknown	9				18	9		36
								(0)
TOTAL	63	109	82	72	109	109	63	607
	(18)	(0)	(36)	(27)	(9)	(27)	(9)	(126)

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

while for severe injuries, they were:

- abdomen-pelvis with exterior contacts (27%),
- chest with door panel (18%), and
- chest with exterior object (18%).

3.4.8 Injuries in Near and 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*) or the opposite side (*FAR*). Previous evidence suggested that there would be differences here (Dalmotas 1983; Otte et al 1984; Rouhana and Foster 1985). Tables 3.18 to 3.23 shows these results where some of the vehicle components (eg; door panels) were re-classified as either near or far (to the occupant) to provide additional information.

NEAR SIDE CRASHES: Table 3.18 shows the results for the 165 near-sided occupants injured in side impact collisions. Most frequent injuries occurred to the upper extremities, chest, abdomen-pelvis, lower limbs and the head for all injuries and to the chest, head, abdomen-pelvis and lower limbs for severe (AIS>2) injuries. Common contact points for minor and major injuries included the near-side door, exterior objects, seat-belt, near-side windows, and the instrument panel. The most frequent injury-source interactions were:

- chest with near door (61%),
- abdomen-pelvis with near door (60%),
- upper extremity with near door (30%),
- lower limbs with near door (27%),
- head with exterior objects (22%), and
- lower limbs with instrument panel (21%).

For severe injuries only, the most frequent combinations were:

- chest with near door (38%),
- abdomen-pelvis with near door (18%),
- head with exterior objects (12%), and
- lower limbs with near door (7%).

Restrained Near-Side Occupants: Restrained near-side occupant injury patterns are shown in Table 3.19 where, on average, these occupants sustained 4.9 injury-source contacts. There were no differences experienced in injuries, contacts, or injury-source combinations for the 134 restrained near-side occupants compared with all near-sided occupants.

Unrestrained Near-Side Occupants: Injury patterns were slightly different for those unrestrained in near-side crashes as shown in Table 3.20 where there were 5.5 injury-source contacts per injured occupant. The most common body regions injured were the upper extremities, lower limbs, head, chest, and face, while for severe injuries only (AIS>2), these included the lower limbs, chest, head, and abdomen-pelvis. Frequent sources of injury included the near-side door, exterior objects, instrument panel, near-side windows and floor and toe pan. The most noteworthy injury-source combinations were:

TABLE 3.18 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO 165 OCCUPANTS INVOLVED IN "NEAR-SIDE" IMPACTS.

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header	1 (1)	2			1			4 (1)
Steering assembly		1	3 (1)		3	1	1 (1)	9 (2)
Instrument panel		2	1 (1)	1	6	21 (4)	1 (1)	32 (6)
Console					1 (1)	4		5 (1)
A-pillar (near)	2	1			1	2 (1)	1 (1)	7 (2)
A-pillar (far)						1 (1)		1 (1)
B-pillar (near)	4 (2)	2	1		5	1 (1)		13 (3)
B-pillar (far)								0 (0)
C-pillar (near)		1			1			2 (0)
C-pillar (far)								0 (0)
Roof side rail (near)	1 (1)	1					1 (1)	3 (2)
Roof side rail (far)								0 (0)
Roof	1	1						2 (0)
Door panel (near)		1	61 (38)	60 (18)	30 (3)	27 (7)	8	187 (66)
Door panel (far)		1			1		1	3 (0)
Side windows (near)	12 (2)	15	1		8		1	37 (2)
Side windows (far)		1						1 (0)
Floor & toe pan						12 (3)		12 (3)
Rear screen & header								0 (0)
Seat	1		1			2	1	5 (0)
Seat belt	3 (1)	2	12	14	5	1	1	38 (1)
Other occupants	1 (1)	1	4 (4)		2	1		9 (5)
Exterior	22 (12)	13 (1)	4 (2)	3 (1)	10 (2)	5 (1)	4 (2)	61 (21)
Indirect	15 (1)			1			1	17 (1)
Other/unknown	16 (5)	11	1	4	19	4	5 (1)	60 (6)
TOTAL	79 (26)	56 (1)	89 (46)	83 (19)	93 (5)	82 (18)	26 (7)	508 (123)

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

TABLE 3.19 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO 134 *RESTRAINED* OCCUPANTS IN "NEAR-SIDE" IMPACTS.

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header	1	1						2 (0)
Steering assembly		1	4 (1)		3	1	1 (1)	10 (2)
Instrument panel		3			6	21 (3)	1	31 (3)
Console					1 (1)	4		5 (1)
A-pillar (near)	2	1				1	1 (1)	5 (1)
A-pillar (far)						1 (1)		1 (1)
B-pillar (near)	4 (2)	2	1		7			14 (2)
B-pillar (far)								0 (0)
C-pillar (near)					1			1 (0)
C-pillar (far)								0 (0)
Roof side rail (near)		1						1 (0)
Roof side rail (far)								0 (0)
Roof	1	1						2 (0)
Door panel (near)	1		63 (40)	61 (16)	30 (3)	27 (6)	9	191 (65)
Door panel (far)					1			1 (0)
Side windows (near)	14 (2)	14			10		1	39 (2)
Side windows (far)		1						1 (0)
Floor & toe pan						10 (1)		10 (1)
Rear screen & header								0 (0)
Seat	1		1			2	1	5 (0)
Seat belt	3 (1)	1	16	16	7	1	1	44 (1)
Other occupants	1 (1)	1	6 (4)		3	1		11 (5)
Exterior	20 (13)	11 (1)	1	1	6 (2)	3	2 (1)	43 (17)
Indirect	16 (1)			1			1	18 (1)
Other/unknown	14 (4)	10	1	3	17	2	4 (1)	51 (5)
TOTAL	78 (24)	48 (1)	91 (45)	82 (16)	91 (6)	74 (11)	22 (4)	486 (107)

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

TABLE 3.20 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO 25 *UNRESTRAINED* OCCUPANTS INVOLVED IN "NEAR-SIDE" IMPACTS.

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header	4 (4)	4			4			12 (4)
Steering assembly					4			4 (0)
Instrument panel			4 (4)	8	8	20 (12)	4 (4)	44 (20)
Console								0 (0)
A-pillar (near)					4	4 (4)		8 (4)
A-pillar (far)								0 (0)
B-pillar (near)	4 (4)	4				4 (4)		12 (8)
B-pillar (far)								0 (0)
C-pillar (near)		4						4 (0)
C-pillar (far)								0 (0)
Roof side rail (near)	4 (4)						4 (4)	8 (8)
Roof side rail (far)								0 (0)
Roof								0 (0)
Door panel (near)			48 (28)	48 (16)	32 (4)	28 (16)	4	160 (64)
Door panel (far)		8					4	12 (0)
Side windows (near)	4	16	4					24 (0)
Side windows (far)								0 (0)
Floor & toe pan						16 (12)		16 (12)
Rear screen & header								0 (0)
Seat						4		4 (0)
Seat belt	4 (4)	4		4				12 (4)
Other occupants								0 (0)
Exterior	32 (12)	24	20 (12)	12 (8)	32	20 (4)	16 (4)	156 (40)
Indirect	8							8 (0)
Other/unknown	20 (4)	12			20	4	8 (4)	64 (8)
TOTAL	80 (32)	76 (0)	76 (44)	72 (24)	104 (4)	100 (52)	40 (16)	548 (172)

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

- chest with near door (48%),
- abdomen-pelvis with near door (48%),
- upper extremity with near door (32%),
- head with exterior objects (32%), and
- upper extremity with exterior objects (32%).

For severe injuries, these included:

- chest with near door (28%),
- abdomen-pelvis with near door (16%),
- lower limbs with near door (16%),
- head with exterior objects (12%),
- chest with exterior objects (12%), and
- lower limbs with instrument panel (12%).

FAR-SIDE CRASHES: Table 3.21 shows the results for the 69 far-sided occupants injured in side impact collisions. The most frequent injuries were to the chest, abdomen-pelvis, upper extremity, and head, while for severe (AIS>2) injuries, they included the chest, head, and abdomen-pelvis. Points of contact were more varied for these occupant injuries and comprised exterior objects, the seat belt, far-side door panel, other occupants, and the instrument panel. Important injury-source contacts for occupants in far-side crashes were:

- lower limb with instrument panel (33%),
- abdomen-pelvis with seat belt (33%),
- chest with seat belt (29%),
- chest with far-side door panel (17%), and
- chest with other occupants (17%).

For severe (AIS>2) injuries, these included:

- chest with other occupant (10%),
- chest with far-side door panel (9%),
- abdomen-pelvis with seat belt (7%), and
- head with exterior object (7%).

Restrained Far-Side Occupants: Table 3.22 illustrates restrained far-side occupant injury patterns where, on average, these occupants sustained 4.9 injury-source contacts. Contrary to other findings, there were differences experienced in injuries, contacts, or injury-source combinations for the 52 restrained far-side occupants. The most frequent body regions injured were the abdomen-pelvis, chest, upper extremities, lower limbs, and the head, while for severe injuries (AIS>2), they included the head, chest, and abdomen-pelvis. Frequent sources of injury included the seat belt, other occupants, instrument panel, far-side door, exterior objects, and the roof. Common injury-source combinations were:

- abdomen-pelvis with seat belt (42%),
- lower limbs with instrument panel (40%),

TABLE 3.21 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO 69 OCCUPANTS INVOLVED IN "FAR-SIDE" IMPACTS.

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header	1						1	2
							(1)	(1)
Steering assembly		1	6	4	6	3		20
			(4)	(1)				(6)
Instrument panel	4	6	1	2	4	33		60
	(3)				(1)	(3)		(7)
Console				3		3		6
								(0)
A-pillar (near)								0
								(0)
A-pillar (far)	3					1	1	6
	(1)							(1)
B-pillar (near)								0
								(0)
B-pillar (far)	1		1		3			6
	(1)		(1)					(2)
C-pillar (near)								0
								(0)
C-pillar (far)	1						1	2
								(0)
Roof side rail (near)								0
								(0)
Roof side rail (far)	1						1	2
							(1)	(1)
Roof	10	7	1		3		3	24
							(1)	(1)
Door panel (near)								0
								(0)
Door panel (far)	8	3	17	9	14	4	4	69
	(4)		(9)	(1)	(1)	(1)		(16)
Side windows (near)								0
								(0)
Side windows (far)	6	7			4			17
	(1)							(1)
Floor & toe pan						3		3
								(0)
Rear screen & header	1	1					1	3
								(0)
Seat	1	1					1	3
								(0)
Seat belt			29	33	12		3	77
				(7)				(7)
Other occupants	9	7	17	13	7	7		60
	(6)	(1)	(10)	(4)	(1)			(22)
Exterior	14	16	9	10	14	12	10	86
	(7)		(3)	(6)	(3)	(1)		(20)
Indirect	1			1				2
				(1)				(1)
Other/unknown	12	12	1	4	9	1	6	46
	(4)		(1)		(1)		(1)	(7)
TOTAL	73	61	82	79	76	67	32	470
	(27)	(1)	(28)	(20)	(7)	(6)	(4)	(92)

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

TABLE 3.22 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO 52 *RESTRAINED* OCCUPANTS IN "FAR-SIDE" IMPACTS.

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header								0 (0)
Steering assembly		2	6 (4)	6 (2)	8	4		26 (6)
Instrument panel	6 (4)	8			6 (2)	40 (4)		60 (10)
Console				4		4		8 (0)
A-pillar (near)								0 (0)
A-pillar (far)	2					2	2	6 (0)
B-pillar (near)								0 (0)
B-pillar (far)					4			4 (0)
C-pillar (near)								0 (0)
C-pillar (far)	2						2	4 (0)
Roof side rail (near)								0 (0)
Roof side rail (far)								0 (0)
Roof	12 (8)	10	2		4		4 (2)	32 (10)
Door panel (near)								0 (0)
Door panel (far)	6 (2)	2	15 (8)	8	14 (2)	6 (2)	4	55 (14)
Side windows (near)								0 (0)
Side windows (far)	4 (2)	6			4			14 (2)
Floor & toe pan						4		4 (0)
Rear screen & header	2							2 (0)
Seat	2						2	4 (0)
Seat belt			35	42 (10)	15		4	96 (10)
Other occupants	12 (8)	8 (2)	21 (12)	16 (4)	10 (2)	10		76 (28)
Exterior	10 (6)	10	4 (2)	4 (2)	10 (2)	4	2	44 (12)
Indirect	2			2 (2)				4 (2)
Other/unknown	13 (4)	13	2 (2)	6	10 (2)		8 (2)	52 (10)
TOTAL	73 (34)	69 (2)	85 (28)	87 (20)	85 (10)	74 (6)	28 (4)	491 (104)

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

TABLE 3.23 BODY REGION/CONTACT SOURCE ANALYSIS FOR ALL INJURIES AND SEVERE (AIS >2) INJURIES TO 11 *UNRESTRAINED* OCCUPANTS INVOLVED IN "FAR-SIDE" IMPACTS.

Source	Head	Face	Chest	Abd-pelvis	Upper ext.	Lower ext.	Neck-Spine	TOTAL
Front screen & header	9						9 (9)	18 (9)
Steering assembly			9 (9)					9 (9)
Instrument panel			9	9		18		36 (0)
Console								0 (0)
A-pillar (near)								0 (0)
A-pillar (far)	9 (9)							9 (9)
B-pillar (near)								0 (0)
B-pillar (far)	9 (9)		9 (9)					18 (18)
C-pillar (near)								0 (0)
C-pillar (far)								0 (0)
Roof side rail (near)								0 (0)
Roof side rail (far)	9						9 (9)	18 (9)
Roof	9 (9)							9 (9)
Door panel (near)								0 (0)
Door panel (far)	18 (18)	9	27 (9)	18 (9)	18		9	99 (36)
Side windows (near)								0 (0)
Side windows (far)	18	18			9			45 (0)
Floor & toe pan								0 (0)
Rear screen & header		9					9	18 (0)
Seat								0 (0)
Seat belt								0 (0)
Other occupants								0 (0)
Exterior	45 (18)	55	36 (9)	45 (27)	45 (9)	55 (9)	55	336 (72)
Other/unknown					9			9 (0)
TOTAL	126 (63)	91 (0)	90 (36)	72 (36)	81 (9)	73 (9)	91 (18)	624 (171)

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

- chest with seat belt (35%),
- chest with other occupant (21%),
- abdomen-pelvis with other occupant (15%), and
- head with other occupant (12%).

For severe injuries, these included:

- chest with other occupant (12%),
- abdomen-pelvis with seat belt (10%),
- chest with far-side door panel (8%),
- head with other occupant (8%), and
- head with roof (8%).

Unrestrained Far-Side Occupants: The final injury pattern examined was for unrestrained occupants in far-side crashes, as shown in Table 3.23. These occupants, on average, sustained 6.2 injury-source contacts per injured occupant. The most common body regions injured were the head, neck-spine, face, chest, and upper extremities, and for severe injuries (AIS>2), the head, chest, abdomen-pelvis, and neck-spine. Frequent sources of injury included exterior objects, the far-side door panel, far-side windows, and exterior objects (B-pillars were especially noted in severe injuries to these occupants). The most noteworthy injury-source combinations were:

- neck-spine, face, and lower limbs with exterior objects (55%), and
- head, abdomen-pelvis, and upper extremities with exterior objects (45%).

For severe injuries, these included:

- abdomen-pelvis with exterior objects (27%),
- head with exterior objects (18%), and
- head with far-side door panel (18%).

3.4.9 Side Impact Summary

Of the 501 crashes containing 605 injured occupants in the Crashed Vehicle File, 40% were side impact collisions. This proportion is considerably higher than that reported by the Transport Accident Commission for Victoria, confirming the greater likelihood of serious injury to occupants involved in side impact crashes.

Drivers comprised 60% of those injured, front-left passengers 27%, and rear seat occupants 13%. These proportions probably reflect exposure rates in the vehicle population as there was no evidence of an abnormal outcome by seating position in this crash configuration.

Ninety percent of all side impacts where someone was injured sufficiently enough to require hospitalisation involved passenger compartment intrusions. Half of them were perpendicular to the direction of travel and half were oblique impact directions.

The average change in velocity on impact (Delta-V) was 35km/h although these values ranged from as little as 8km/h to over 96km/h Eighty-nine percent were equal to or below 54km/h, while 36% were equal to or below 27km/h, the perpendicular component proposed for the American side impact test.

Eighty-four percent of injured occupants wore their seat belt at the time of the collision. Rates in the front seat were higher than in the rear but overall were less than that expected from population statistics. This suggests that even in side impacts, seat belts help reduce injury.

Thirty nine percent of restrained and 14% of unrestrained occupants were entrapped from these collisions. There were only a few cases of occupant ejections amongst belt wearers, yet more than one-third of unrestrained injured occupants experienced ejection to some degree.

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.

The average level of injury severity (ISS) for this sample of hospitalised and killed side impact occupants was almost twice that of their frontal crash counterparts. Similarly, the proportion of killed to hospitalised occupants was also markedly higher for side impact than frontal crashes.

Occupants of vehicles involved in side impacts sustained a high proportion of severe injuries to the chest, head, abdomen-pelvis and lower limbs from contacts, mainly with the door panel and exterior objects, but also involving the instrument panel and side windows. There was little indication that the steering assembly was especially hazardous to front seat occupants in these impacts.

There were roughly twice as many "*near-side*" impacts as there were "*far-side*" crashes in the sample, although a sizeable number of occupants still sustained severe injuries from far-side contacts (especially involving contacts with the seat belt opposite side door panel and side windows and the instrument panel). Far-side contacts were noticeably different in that contacts with other occupants gained in importance in their injurious effects.

4. DISCUSSION AND RECOMMENDATIONS

The results of this analysis of 198 side impact crashes involving 234 hospitalised or killed occupants has uncovered several important findings that need to be elaborated upon. This final chapter discusses these findings in relation to results reported by other similar studies overseas and makes a number of recommendations for design improvements to reduce the frequency or severity of injury to occupants involved in side impact collisions in Australian passenger cars.

4.1 SEVERITY OF SIDE IMPACT CRASHES

The relative severity of these crashes compared to other crash configurations has been mentioned earlier. The average change in velocity of impact was lower, but the average injury severity score, the proportion of killed to hospitalised occupants, and the probability of serious injury were all higher for side than frontal crashes. Furthermore, the proportion of side impacts among this representative sample of severely injured Victorian crashes was much higher than that reported for all Victorian injury crashes over the same time period by the Transport Accident Commission of Victoria (Fildes et al 1991).

This is not a new finding and has been previously reported by other researchers in Australia and overseas (eg; Marcus et al 1983; Mackay et al 1991; Fan 1987). The proportion of side impact **Harm** is higher among this sample than that reported for the USA during the 1980's by Malliaris et al (1982), presumably because of the higher belt wearing rates in Australia and the resultant disproportionate reductions in frontal Harm as a consequence in this country. It may also be that there are proportionately more side impacts in Australia.

As noted in the literature review, side impacts do present a particularly difficult problem for secondary safety improvement because there is little crushable structure and distance between the impacting car or object in a side crash and near-side occupants. As Cesari and Bloch (1984) reported, the front structure of the car is able to absorb two to five times as much energy as the side structure before injury occurs. The results obtained here generally support this claim, although the precise difference in energy absorption between side and front crashes in the sample is difficult to assess, given the confounding effects of variations in delta-V and injury severity for both configurations noted above.

4.2 OVERVIEW OF CRASH AND OCCUPANT CHARACTERISTICS

Of the 501 crashes containing 605 injured or killed occupants in the Crashed Vehicle File, 40% involved side impact collisions, either with another vehicle or a fixed object. Ninety percent of these injurious crashes involved impact with the passenger compartment and subsequent intrusion. Half of them were perpendicular to the direction of travel of the observed vehicle while the other half occurred at some oblique angle.

Mackay (1990) reported similar findings from investigations in the UK, although he noted a slightly higher non-compartment involvement rate (20% c.f 10%). This might simply reflect minor differences in the way compartment involvement is coded between the two studies or possible beneficial effects for the Australian car fleet. A higher proportion of larger cars in Australia compared to the UK could conceivably mean that compartment involvement is necessary in side impacts in this country before occupants are injured. This finding warrants closer examination.

4.2.1 Side Impact Integrity

Given the minimal space and structure between the impacting vehicle or object and the occupants in side impacts, its not too surprising that intrusions into the passenger compartment are quite frequent among these injury crashes. Roughly nine out of ten front doors and three out of four back doors were deformed during these crashes suggesting the need for further improvement in side impact integrity in Australian passenger cars. B-pillars were more commonly deformed than either A- or C-pillars, highlighting the relative importance of this central door structure and the need for it to be emphasised in efforts to improve side impact strength.

Somewhat surprisingly, the roof and roof side rail were deformed in only 14 and 20 percent of side crashes in the front (and 15 and 13 percent in the rear). Clearly, this shows the relative importance for improved side impact integrity to focus on the lower half of the side of the vehicle, especially the door panel and below.

Intrusions involving the steering assembly were less apparent (and probably less critical as well) in side than frontal impacts. Nevertheless, there were a sizable proportion of steering wheel movements both laterally and vertically in these crashes. While the steering wheel did not feature prominently as an injury source in this analysis, there were a number of instances of severe injuries to the chest and abdomen-pelvis among drivers in side impacts. The need for performance specifications in these two directions was noted for frontal crashes in CR 95 (Fildes et al 1991) and these side impact findings further support this recommendation.

4.2.2 Occupant Characteristics

Sixty percent of patients were drivers, 27 percent front-left passengers, and 13 percent rear seat passengers, which is not too different from seat exposure rates except for the rear seat. There were no signs of over-involvement for either males or females and most age groups and only those aged over 75 years seemed over-represented from population statistics. This can be explained, however, purely in terms of the frailty of the aged.

Seat belts are commonly thought to be principally a frontal crash countermeasure and offer little benefit for occupants in side impacts. However, the finding here that 16% of front seat and roughly half rear seat injured occupants did not wear their seat belt was markedly higher than that reported among the population at large (6% and 34% respectively, Vic Roads 1990; Ove Arup 1990).

While overseas figures are less compelling, nevertheless Mackay (1988) and Jones (1982) have argued that the three-point belt still has a substantial protective effect in side impacts most notably, they claimed, for far-side occupants. The results from this study suggest that three-point seat belts are also an advantage for near-side occupants as well, if only in preventing ejections and severe injury from exterior contacts. It should be pointed out, however, that the over-involvement of non-restrained occupants observed in this study might also reflect a tendency for these motorists to be over-involved in side impacts crashes as well.

Jones (1982) reported that seat belts also prevent contacts between occupants in side impact crashes but this was not repeated here. In fact, there were no recorded contacts from other passengers for unbelted occupants in this study which seems a little puzzling. It might be that there were too few unbelted cases for this trend to be apparent (17 drivers, 8 FLP and 11 rear passengers) especially when many of these occupants may have been the only lateral occupant in that seating position (eg; drivers are only likely to have a FLP in roughly half of rural trips and one-quarter urban trips; Fildes Rumbold and Leening (1991)). It might also be that unbelted occupants are more likely to be ejected from their vehicle, hence they are less likely to come into contact with other occupants. This warrants further investigation.

4.2.3 Entrapments and Ejections

There was a higher tendency for seat belt wearers to be entrapped in these collisions than non-wearers (39% c.f. 14%). However, it is not clear what effect this may have had in terms of injuries or survival rates for these occupants, given the number of confounding factors apparent in these data. Clearly, it is undesirable to be entrapped after a crash. It runs the risk of incineration in the case of fire or drowning if the car is subsequently immersed. Moreover, long delays in removing occupants after a crash can leave the individual with severe physical and psychological consequences. apart from any additional injuries that might be sustained in removing someone trapped inside a vehicle. It is not a consequence to be encouraged.

Ejections, on the other hand, were practically non-existent among belt wearers (2 percent) compared with a 38 percent rate for unrestrained occupants in these crashes. Moreover. injuries and injury sources reflected a higher proportion of severe injuries from external contact sources among those not wearing their seat belts. This is further evidence of the benefit of seat belts in reducing injuries for occupants in side impact crashes discussed above. It might also help to explain the anomaly described above for contacts with "other occupants".

4.3 INJURIES AND CONTACTS

The study set out to examine the various types and frequencies of injuries sustained by occupants in side impact crashes and the contacts within the car as well as exterior objects associated with these injuries. Injuries and contact points are discussed both separately and as interactions below to further identify patterns of injury and areas requiring intervention.

4.3.1 Body Regions Injured

While drivers sustained marginally more injuries than other occupants, there were no major differences observed in terms of injury severity or the probability of injury across the various seating positions.

Front seat occupants sustained a significant number of head. chest, upper extremity, and abdominal-pelvic injuries, including severe injury to many of these regions. Rear seat passengers had fewer head injuries but were equally vulnerable to chest, abdominal-pelvic. and upper extremity injury. There were roughly equal numbers of neck-spinal injuries across the various front and rear seating positions.

These findings are not that different from those reported by Holt and Vasey (1977) from early Australian data and Dalmotas (1983) from Canadian statistics. Lestina et al (1990) also reported that head. chest. and abdominal injuries predominated among severe (AIS>2) injury to UK occupants which again is similar to that found here. The fact that there have been few changes in the Australian injury pattern over the last 15 years or so demonstrates the need for further effort at improving occupant protection in side impact crashes.

4.3.2 Frequent Points of Contact

By far the greatest source of injury for all occupants in side impact crashes was the door panel (between 55 and 84 percent of injuries were from this source). Seat belts and the instrument panel were the next major sources of injury in the front seat while exterior contacts and the side window and frame were also significant. For rear seat passengers, exterior objects and window and frame contacts rated more highly, presumably because of the lower seat belt wearing rates in the back seat and the higher propensity for ejection among unrestrained occupants.

The door panel has been reported previously as the most frequent impacting part by Dalmotas (1983), Otte et al (1984), Hackney et al (1987), and Haalund (1991). However, the substantial number of seat belt injuries observed in these side impact crashes has not been previously highlighted. This is probably a consequence of current high seat belt wearing rates in Australia and the relatively low wearing rates in the older overseas studies. Similarly, while some of the previous studies have reported much higher involvement from the side rails, pillars and roof to that observed here, this is also likely to be a consequence of higher unrestrained occupant populations.

4.3.3 Injuries By Contact Sources

The most informative injury-source results were obtained by scoring the various interactions between injuries and contact points for each one hundred occupants. These were able to be broken down by seating position, near- and far-side impact, and belt wearing status. These are discussed in terms of the factors of most relevance.

SEATING POSITION: The results for drivers and front-left passengers were remarkably similar for these side crashes. Injuries to the chest and abdomen-pelvis from the door were most frequent for all as well as severe injuries; two-thirds of all these injured occupants sustained such an injury and one third were greater than AIS2 severity. Head injuries from contact with an exterior object were also particularly noteworthy among the more severe injuries. Lower limb injuries from the contact with the instrument panel and chest injuries from the seat belt were also quite common, although they tended to be less severe injuries overall.

Rear seat occupants also experienced a sizable number of chest and upper extremity injuries from contact with the door, although not as frequently as front seat occupants did. Of particular concern was the high number of chest, upper extremity, and abdomen-pelvic injuries (but not head strangely enough) from external contacts. This clearly reflects the higher proportion of unrestrained injured occupants in the rear and the greater likelihood of severe injury from external objects presumably after ejection.

It was not possible to compare these injury-source findings with others in the literature as most previous reports on injuries sustained in side impact collisions have stopped short of providing this level of detail.

RESTRAINT EFFECTS: As noted above, there were differences observed in the body regions injured and the sources of injuries between restrained and unrestrained occupants. Except for drivers, there were generally higher rates of injury-source contacts per 100 injured occupants for those unrestrained than those who were restrained. This further demonstrates the protective effects of seat belts in minimising injuries in side impacts.

The findings for restrained front seat occupants were not too dissimilar to the findings for all front seat occupants which is understandable, given their high proportion. However, unrestrained front seat occupants experienced many more contacts with exterior objects (especially among the more severe injuries) compared to restrained front seat occupants which no doubt reflects the greater propensity for ejection. Front left passengers experienced many more contacts with other occupants, presumably because they always have another occupant (the driver) whereas drivers are much less exposed to front left passengers. A higher proportion of severe lower limb injuries from contact with the door, floor, and instrument panel was also noted for unrestrained drivers and front left passengers.

Examining across restraint condition in the rear, it becomes apparent that exterior contacts account for most injuries to these unrestrained occupants. For restrained rear seat occupants, the door panel and window and frame were predominantly associated with their injuries. Clearly, a sizable number of severe injuries to rear seat passengers could be reduced simply by increasing seat belt wearing rates, although there is also a need to consider how to reduce injuries from contact with the rear doors and windows, too.

SIDE OF IMPACT: As noted earlier, there was a much higher proportion of near-side than far-side occupants in the sample. Others such as Dalmotas (1983), Hackney et al (1987) and Haalund (1991) have also observed the injury benefit of being seated away from the side of impact and disbenefit of being on the impacted side. Moreover, differences in injuries and contacts have been attributed to the relationship between seated and impacted side.

Near-sided occupants experienced many more contacts with the near-side door involving the chest, abdomen-pelvis, upper arms, and lower limbs. Furthermore, many of the upper torso injuries were severe life threatening injuries (AIS>2). This was especially so for restrained occupants, although not infrequent among unrestrained near-side occupants, too. Clearly, there is an urgent need to address ways in which these injuries from the door panel itself can be mitigated through improved padding and a more forgiving structure.

In far-side crashes, there were many more seat belt induced injuries (especially among those restrained) suggesting that present seat belt designs in both the front and rear seats is not optimal for this crash type. There was also a number of severe chest injuries still from contact with the far-side door and from other occupants. In addition, there was a disconcerting number of severe head injuries from the far-side door and exterior objects to both restrained and unrestrained occupants alike in these crashes. This suggests that measures aimed at keeping occupants apart and away from the impacting side would also be of benefit in reducing injuries to vehicle occupants in side impact crashes.

4.4 SIDE IMPACT COUNTERMEASURES

Side impacts were involved in 40 percent of the crashes investigated in this study and are estimated to cost the Australian community around A$1 billion in Harm annually (1991 prices). This represents a major source of road trauma in this country that needs to be addressed. The results obtained in this study suggest a number of possible countermeasures to alleviate injuries to occupants in side impact crashes which are detailed below.

4.4.1 Side Door Padding

The most common source of injury (involving both minor and major injuries) to the chest and abdomen-pelvic regions of the body for those involved in these crashes was the door panel. This was so for both near- and far-side impacts, although its role was clearly more predominant for those seated on the impacted side. As noted above, this has also been reported elsewhere and means for alleviating these injuries have been subject to research and development overseas.

The role of the vehicle's structure in mitigating door intrusions is one area that warrants closer attention (this is discussed further in terms of structural performance standards). However, most overseas experts have also acknowledged that better padding of the door surface itself can play a role in helping to reduce torso injuries. The suitability of various types of padding is subject to current research effort involving car manufacturers, material engineers, and research groups. It has been argued that appropriate padding can mitigate SID dummy loads (and presumably impact injuries) by up to 30 percent (Preuss & Wasko 1987), although the basis for finding has been questioned by Lau and Viano (1988).

Types of padding (and various thicknesses of padding) explored so far include soft foams and hard polystyrene materials, as well as other forms of padding (aircups, honeycomb structures, etc). Manufacturers wishing to optimise injury reductions have experimented with various combinations of these materials (refer the proceedings of the 1991 Experimental Safety Vehicles conference for a plethora of papers describing these tests and findings). The distance, too, between the surface of the padding and the near-side occupant also appears relevant in terms of reducing peak occupant loads in side crashes (Preuss & Wasko 1987; Gabler. Hackney & Hollowell 1989).

4.4.2 Side Door Airbags

The development of airbags in the doors of vehicles has also received attention recently as a means of further mitigating door impact injuries to the chest, abdomen and pelvis. Several manufacturers including Volvo (in conjunction with Autoliv) are developing a low volume (8 litre) side airbag that will inflate rapidly upon impact and provide ride-down with some padding and separation benefits for the near-side occupants from the intruding door surface. While the side airbag is still in the development phase, early estimates of its injury reduction benefits are encouraging. Olsson, Skötte and Svensson (1989) claim that this 8 litre bag should reduce injuries to the upper torso by 20 to 30% and head ejection by approximately 80 mm.

The Volvo/Autoliv airbag is essentially a door cushion that provides torso benefits to occupants in side impact collisions. However, Toyota have been experimenting with an alternative (possibly supplementary) airbag that is fitted to the top of the door panel and inflates outwardly and upwards upon impact. This bag has the potential to provide benefit not only to the upper torso (chest and shoulder region) from contacts with the door, but to the head as well from contacts with the window and surround and from outside sources (eg; the bonnet of the impacting vehicle or object).

The Toyota airbag is a promising development in side impact protection that deserves continuing support. While there seem to be a number of difficulties to be overcome yet (such as ensuring it reaches position in time to cushion head movements and is not destroyed by the impacted side window), nevertheless it is a real attempt to minimise head and face injuries from window and exterior contacts and likely to have high benefits in reducing this trauma.

4.4.3 Improved Side Glazing

Head and face contacts with the side glazing and exterior objects were noted to be of concern among some of the cases examined in this study. Another means of reducing head and face contacts with exterior objects that has received some attention among safety researchers is the need for improved side glazing to reduce the probability of partial head ejections and strikes with impacting surfaces. It is understood that some expensive models overseas are fitting double glazed side windows (primarily for sound attenuation) with plastic laminate layers sandwiched in-between. This has the potential to act as a head retention barrier which should mitigate injury severity. It would be worth monitoring progress in this area and where possible. evaluating the relative effectiveness of vehicles fitted with double glazed windows over conventional window safety performance.

4.4.4 Improved Seat Belt Wearing

The results of this study (and others overseas) demonstrate that seat belts are still a benefit for occupant protection in side impact crashes. As shown in the previous frontal crash report (CR 95, Fildes et al 1991), there was an over-representation of non-belt wearers among the injured sample of side impact vehicle occupants to that observed among the general motoring population (13% cf 6% in the front and 46% cf 34% in the rear). Moreover, those wearing belts had fewer injuries on average and had practically no injuries from being ejected from the vehicle than non-wearers. While this might also indicate a tendency for unrestrained occupants to be over-involved in crashes, it almost certainly shows that those not wearing seat belts are more likely to be injured and injured severely.

Further efforts to improve seat belt wearing rates are clearly warranted from these findings. In particular, measures to ensure that occupants in the rear seat are properly restrained would yield substantial savings in rear seat trauma. The previous report proposed a seat belt warning system that alerted the driver when an occupant (essentially in the front but could be expanded to include the rear as well) was not restrained and this was subsequently shown to be very cost effective (Report CR 100, Monash University Accident Research Centre, 1992).

A fixed period seat belt warning light has been included in the new proposed Frontal Crash Performance requirement for new passenger cars ADR 69/00. However, it was primarily aimed at frontal passengers and may not directly influence those in the rear. Thus. is might be useful to re-examine the whole question of a seat belt warning device for both front and rear seat passengers, and especially the need for seat sensing and continual warning when seat belts are not being used.

4.4.5 Improved Seat Belt Systems

While seat belts have some effect in minimising side impact trauma (especially in preventing ejection and injuries from exterior contacts), nevertheless there were still a number of injuries from contact with the belt or belt attachments in this sample of occupants. These included both front seat and rear seat passengers. Some of these injuries would have been the result of inappropriate occupant movements (eg: lateral displacement in a system primarily designed for longitudinal displacement). However, some of the injuries may have been prevented or mitigated if the seat belt system was more restraining. A number of measures aimed at improving seat belt geometry were identified in CR 95 including better alignment characteristics (from attachment of the belt to the seat), less webbing spool out (from belt pre-tensioners and webbing clamps), and improved seat design (to reduce submarining). These improvements for both front and rear seat occupants are also likely to have some side impact benefits as well and are worth pursuing.

4.4.6 Lower Instrument Panel Protection

Lower limb injuries to front seat occupants from contacts with the instrument panel were observed in many of these side crashes. This is not too surprising, given that roughly half of these were oblique angled impacts. There was a high incidence of these injuries also in frontal crashes and the need for more forgiving lower instrument panels and kneebars was highlighted in the previous report (CR 95). While the new frontal crash performance standard does specify maximum femur loading, this is not likely to be sufficient in itself to ensure a reduction in lower limb injuries (which are extremely disabilitating and costly to the community). Further efforts to identify the various types and mechanisms of lower limb injuries and subsequently acceptable performance requirements to mitigate these injuries are urgently needed.

4.4.7 Occupant Separation

Some injuries were observed from contact with other occupants in the same lateral position. This was especially so for front seat passengers and for far-side collisions; there was presumably a higher likelihood for another occupant on-board in the front seat than the rear (ie; all cars have a driver) and the crash dynamics practically ensure contact in perpendicular side impacts. This has also been reported previously by Faerber (1983) and Strother et al (1984), although Jones (1982) claimed that seat belts reduce these injury-source contacts. Interestingly, though, no "*other occupant*" contacts were observed among unrestrained front-left passengers (or any unrestrained occupants for that matter) in this study.

Alternative means of separating occupants in side impact collisions are worth considering. While higher seat belt wearing rates may not be the answer, better fitting belt systems may still have some positive effects. Other ingenious measures such as wrap-around (wing-sided) front seats, especially pronounced on the in-board side, and/or console airbags may be possible solutions for the future protection of occupants in side crashes. However, suitable devices have yet to be developed or shown to alleviate these injuries.

4.4.8 Side Structural Improvements

The role of improved side structure for greater occupant protection is not clear at this stage. Increasing the strength, stiffness and integrity of the side of the car adjacent to the occupants would seem intuitively sensible to reduce injuries from side impacts with non-rigid structures such as other cars by providing more resistance to intrusion. The Side Impact Protection (SIPS) system introduced recently by Volvo is mainly focused on these types of structural improvements and they claim a 25% reduction in upper torso injuries for this system (Planath 1993). However, the role of greater structural strength for impacts with other rigid structures (poles, barriers, trucks, etc.) has been questioned by Mackay (1990). He argued that under these circumstances, an occupant may be subjected to greater loads and that structural integrity may need to be improved substantially before injurious intrusions are mitigated to any degree. Other authors (eg Aldman 1988) have claimed that structural benefits will only be achieved with lower bumpers and more rigid sill panels to increase the lateral acceleration of the impacted vehicle, and hence minimise door intrusions.

4.4.9 Steering Column Movements

There were frequent instances of lateral and vertical steering wheel movements observed in side impact crashes in this study. While the steering assembly did not rate highly as a source of injury, nevertheless, intrusions into the space normally associated with projectile body movements in crashes cannot be a desirable feature. The results of this study support previous calls for further specification of allowable steering assembly movements in other than longitudinal directions (Fildes et al 1991).

4.4.10 Reduced Side Impact Opportunities

It was noted earlier that side impacts present a particularly difficult problem for secondary crash protection as there is little crushable structure available between the occupant and the impacting vehicle or object. Given the severe limitations therefore in providing occupant protection in these severe crash types, perhaps attention also needs to be given to primary safety measures to alleviate side impact crash opportunities. This may be a special case where an ounce of prevention is worth much more than a pound of protection.

There are several ways of reducing the likelihood of side impacts on our roads. First, a greater use of roundabouts and staggered T intersections will minimise the opportunities for high speed impacts by forcing intersecting traffic to slow down at intersections. Second, the installation of traffic signals at locations with high incidence of side impact crashes has been shown to be effective in reducing these crashes. There is a growing body of evidence that demonstrates these approaches are likely to have considerable impact on reducing side impact crashes. Furthermore, reducing the number of intersections (and in particular direct access of local streets onto major arterials) will reduce the exposure opportunities for side impacts. Finally, the use of bridges or tunnels in the planning and construction of new roads where traffic flow is essentially cross-flow will also remove the opportunity for these severe crashes to occur.

4.5 A NEW SIDE IMPACT STANDARD FOR AUSTRALIA

Australia is the only country outside North America to have a side impact standard. Australian Design Rule ADR 29, which effectively took on-board the early US FMVSS 214 standard, specifies the amount of intrusion permissible from a static load test, resulting in side impact beams being fitted to most Australian vehicles. While Cameron (1980) was unable to show any statistical evidence that ADR 29 reduced the risk of injury to front seat passengers, he nevertheless recognised that limitations existed with the data set available at that time. Kahane in the US did manage to show the benefits of their standard using a much larger database. The findings from this study of crashed vehicles, however, clearly demonstrate the urgent need for further improvements in side impact protection for Australian passenger car occupants.

Chapter 2 reports on recent developments towards improved side impact standards in both the U.S.A.and Europe. It is true to say that recent events in these two regions of the world have not enhanced the development of an effective standard. The US have "*bitten the bullet*" and regulated an improved FMVSS 214, encompassing a dynamic crash test requirement due to be introduced in 10% of new 1994 passenger cars (models that go on sale in September 1993). However, there is grave concern expressed by some researchers in the US and Europe that this standard may not necessarily lead to the level of protection it seeks to provide because of inadequacies in the test dummy, injury criteria, and crash configuration.

On the other hand, the Europeans seem less able to agree on what constitutes an acceptable alternative. While their EUROSID test dummy is claimed to be a more effective measure of occupant trauma than SID, implementation of a European standard seems to be some way off yet and is subject to on-going tests and debate among the European participants. This places Australia in a difficult position, especially with a need for all new ADR's to harmonise with internationally accepted performance standards.

One possibility for improved occupant protection in side impacts would be to accept the US standard in its present form as an immediate Australian requirement. It could be argued that most overseas manufacturers will be forced to meet this standard in future and, therefore, it constitutes an acceptable regulation and will provide better protection than no performance standard at all. However, this may unduly penalise overseas makers who choose to make RH drive vehicles that meet the European standard only.

Another option then might be for Australia to accept either standard for compliance purposes, assuming the European standard is ultimately implemented as proposed. It would be expected that manufacturers will find ways around areas of conflict between the two standards and that ultimately these experiences will lead to additional side impact improvements. This would also ensure that Australia is not locked into any one of these international standards should either be subsequently shown to be sub-optimal.

In any event, it would be worthwhile determining the likely benefits and costs if both regulations were to apply in this country. Benefits could be determined using a Harm reduction approach, although many of the assumptions may need to be "*best estimates*" given the lack of injury mitigation data and documented evaluation studies. Costs would be even more difficult to assess and could require modelling or crash testing various alternative design improvements necessary to meet these standards.

In the meantime, manufacturers should be encouraged to improve side impact protection for occupants in new vehicles by implementing some of the countermeasures discussed above where appropriate for their models. In addition to monitoring this progress, the government could also encourage investment in road and traffic engineering measures which have been shown to be cost effective in reducing the incidence of side impact collisions.

REFERENCES

ALDMAN B. (1988). Notes from discussions held between B. Aldman and B. Fildes during a visit to Sweden in May 1988.

ARDOINO, P.L. (1983). Occupant kinematics in side collision. **Proceedings, Biomechanics of impacts in road accidents**, 113-131, Fiat Safety Centre, Commission of the European Communities, Brussels.

BAKER, S.P., O'NEILL, B., HADDON, W. Jr., et al., (1974). The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care, **Journal of Trauma, 14**, 187-196.

BENDJELLAL, F., TARRIERE, C., BRUN-CASSAN, F., FORET-BRUNO, J.Y., CAILLIBOT, P. & GILLET, D. (1988). Comparative evaluation of the biofidelity of EUROSID and SID side impact dummies. **32nd STAPP Car Crash Conference Proceedings, P-215**, 237-278. SAE paper 881717. Society of Automotive Engineers Inc., Warrendale, PA, USA.

BRUBAKER, W. & TOMMASSONI, J. (1983). Some special analyses of thoracic protection in side impact. SAE paper 830466. Soc. of Automotive Engineers. Warrendale, PA.

BURGETT, A. & BRUBAKER, W. (1982). The role of the side of the motor vehicle in crash protection. **Crash Protection Conference, P-513**, 65-86, SAE paper 820245. Society of Automotive Engineers, Warrendale, PA, USA.

CAMERON, M. H. (1980). Side impacts and the effect of Australian Design Rule 29 for side door strength: a preliminary study. Report CR14, Federal Office of Road Safety, Dept of Transport, Canberra, Australia.

CAMPBELL, K.L., SMITH, E.J., WASKO, R.J. & HENSEN, S.E. (1989). Analysis of the JAMA side impact test data. **33rd STAPP Car Crash Conference Proceedings, P-227**, 87-100, SAE paper 892430, Washington, D.C., USA.

CAREINE, L.M.M. (1991), Occupant kinematics and injury causation in side impacts - field accident experience. In SP-851, Side impact occupant technologies, 1-15, Society of Automotive Engineers, Warrendale, PA.

CAVANAUGH, J.M., WALILKO, T.J., MALHOTRA, A., ZHU, Y. & KING, A.I. (1990), Biomechanical response and injury tolerance of the pelvis in twelve sled side impacts, **Thirty-fourth Stapp Car Crash Conference,** SAE P-236, 1-12. Society of Automotive Engineeers, Warrendale, PA.

CAVANAUGH, J.M., ZHU, Y. HUANG, Y. & KING, A.I. (1993), Injury and response of the thorax in side impact cadaveric tests, **Thirty-seventh Stapp Car Crash Conference,** SAE P-269, 199-222. Society of Automotive Engineeers, Warrendale, PA.

CESARI D. (1983). A review of injury mechanisms, tolerance data and protection criteria in side impact accidents, Proceedings of a Seminar on Biomechnaics of Impacts in Road Accidents, EUR8939 EN, Commission of the European Communities, Brussels, pp 132-149.

CESARI, D. & BLOCH, J. (1984). The influence of car structures behaviour on occupant protection in car to car side impact. **Vehicle Structures, International Conference on Vehicle Structures,** C163/84, 7-10, Mechanical Engineering Publications Ltd., London, England.

CESARI, D. & RAMET, M. (1982). Pelvic tolerance and protection criteria in side impact. **Twenty-sixth STAPP Car Crash Conference Proceedings, P-113**, 145-154, SAE paper 821159. Society of Automative Engineers. Warrendale, PA, USA.

CROMARK J.R., SCHNEIDER D. & BLAISDELL D. (1990). Occupant kinematics and belt marking in crash tests with unrestrained and partially restrained test dummies, **Proceedings of the 34th Conference of the Association for the Advancement of Automotive Medicine, Vol 34**, 203-225.

DALMOTAS, D.J. (1983). Injury mechanisms to occupants restrained by three-point seat belts in side impact. **SAE Transactions, 92(2)**, 2.328-2.354, SAE paper 830462. Society of Automotive Engineers Inc., Warrendale, PA, USA.

DANIEL, R.P. (1989). Biomechanical design considerations for side impact. Side Impact: Injury Causation & Occupant Protection, SAE SP-769, 71-84. Society of Automotive Engineers, Warrendale, PA.

DENG, Y-C. (1988). Design considerations for occupant protection in side impact - a modelling approach. **32nd STAPP Car Crash Conference Proceedings, P-215**, 71-79, SAE paper 881713. Society of Automotive Engineers Inc., Warrendale, PA, USA.

DENG, Y-C. (1989). The importance of the test method in determining the effects of door padding in side impact. **33rd STAPP Car Crash Conference Proceedings, P-227**, 79-85, SAE paper 892429. Society of Automotive Engineers, Washington, D.C.

EPPINGER, R.H., MARCUS, J.H. & MORGAN, R.M. (1984). Development of dummy and injury index for NHTSA's Thoracic Side Impact Protection Research Program, **SAE Transactions, 93**, 4.359- 4.387, SAE paper 840885.

EPPINGER, R. (1992), Thoracic and abdominal injuries. **Crash Injury Biomechanics**, Conference Proceedings. Adelaide, NHMRC Road Accident Research Unit.

FAERBER, E. (1983). Interaction of car passengers in side collisions - tests with four new side impact dummies. **Twenty- seventh STAPP Car Crash Conference Proceedings, P-134**, 407-417, SAE paper 831633. Society of Automotive Engineers Inc., Warrendale, PA, USA.

FAN, W.R.S. (1987). Two new areas concerning side impact protection for passenger car occupants, **SAE Transactions, 96**, 3.315-3.326, SAE paper 871114. Society of Automotive Engineers, Warrendale, PA.

FILDES B.N. (1988). Personnel communication with Mr. Jeffery Silver, President of the Inter-Industry Conference on Automobile Collision & Repair (a non-profit repair industry training center), Wood Dale, Ilinois.

FILDES, B.N. & VULCAN, A.P. (1989). Report on overseas visits to discuss vehicle occupant protection. Monash University Accident Research Centre, Report MR1, Federal Office of Road Safety, Department of Transport and Communications, Canberra, Australia.

FILDES, B.N. & VULCAN, A.P. (1990). Crash performance and occupant safety in passenger cars involved in side impacts. **Proceedings of the 1990 IRCOBI Conference on the Biomechanics of Impacts**, Bron, France.

FILDES. B.N.. LANE, J.C., LENARD, J. & VULCAN. A.P.. (1991), Passenger cars and occupant safety. Report CR95. Federal Office of Road Safety, Canberra.

FILDES B.N., RUMBOLD G. & LEENING A. (1991). Speed behaviour and drivers' attitudes to speeding, Report No.16, Monash University Accident Research Centre, Melbourne, Australia.

FRIEDEL, B. (1988). Side collisions and crash worthiness. **VTIrapport-Proceedings of Road and Traffic Safety On Two Continents.332A**, 237-259, Swedish Road and Traffic Research Institute, Linkoping, Sweden.

GABLER, H.P., HACKNEY, J.R. & HOLLOWELL, W.T. (1989). DEPTH: a relationship between side impact thoracic injury and vehicle design. **Twelfth International Conference on Experimental Safety Vehicles, Proceedings**, Vol 2, 994-1007.

HÄLAND, Y. (1991). Car to car impacts. Occupant injuries and a new subsystem test method to evaluate protective systems. Thesis, Chalmers Teckniska Hoegskola, Goteborg [abstract].

HACKNEY, J.R., GABLER, H.C., KANIANTHRA, J.N. & COHEN, D.S. (1987). Update of the NHTSA research activity in thoracic side impact protection for the front seat occupant. **31st STAPP Car Crash Conference Proceedings, P-202**, 129-142, SAE paper 872207. Society of Automotive Engineers Inc., Warrendale. PA, USA.

HARDY, R.N. & SUTHURST, G.D. (1985). Simulations to asess the influence of car lateral impact characteristics on occupant kinematics. **Proc. Institution of Mechanical Engineers. 199 No D2**, 97-104, Institute of Mechanical Engineers.

HARGRAVE, M., HANSEN, A.G. & HINCH. A.J. (1989). A summary of recent side impact research conducted by the Federal Highway Administration. Dide Impact: Injury Causation & Occupant Protection, SAE SP-769, 7-20. Society of Automotive Engineers, Warrendale, PA.

HENRY, C., THOMAS, C., FAVERJOHN, G., TARRIERE, C., GOT, C. & PATEL, A. (1989). Side impacts: expected benefits of planned standards. **Twelfth International Conference on Experimental Safety Vehicles**, Vol 2, 913-919. U.S. Department of Transportation.

HOBBS, C.A. & LANGDON. M.G. (1988). Thoracic impact and injury in side impact accidents. **Proceedings of the 1988 International IRCOBI Conference on the Biomechanics of Impacts**, 345-360, Bron, France.

HOLT, B.W. & VAZEY, B.A. (1977). In depth study of seriously injured seat belt wearers. Report number 1/77, Traffic Accident Research Unit, Dept. of Motor Transport. New South Wales, Australia.

HUANG, Y.. KING, A.I. & CAVANAUGH. J.M. (1993). A Madymo model of near-side human occupants in side impact. Paper presented to the ISO TC22/WG6. Paris.

HUELKE. D.F., SHERMAN. H.W. & STEIGMAYER, J.L. (1989). Side impacts to the passenger compartment - clinical studies from field accident investigations. Side Impacts: Injury Causation and Occupant Protection, SAE SP-769, 21-31. Society of Automotive Engineers. Warrendale . PA.

INSURANCE INSTITUTE FOR HIGHWAY SAFETY (1992). Crash test dummy development - front and side impact dummies of the present, future, **Status Report, 27(15)**, pp 7, Arlington, VA.

IRWIN, A.L., PRICOPIO, L.A., MERTZ, H.J., BALSER, J.S. & CHKOREFF, W.M. (1989). Comparison of the EUROSID and SID impact responses to the response corridors of the International Standards Organisation. Side Impact: Injury Causation & Occupant Protection, SAE SP-769, 103-131. Society of Automotive Engineers, Warrendale, PA.

JANSSEN, E.G. & VERMISSEN, A.C.M. (1988). Biofidelity of the European side impact dummy - EUOROSID. **32nd STAPP Car Crash Conference Proceedings, P-215**. 101-124, SAE paper 881716. Society of Automotive Engineers Inc., Warrendale, PA.

JONES, I.S. (1982). Injury severity versus crash severity for front seat car occupants involved in front and side impacts. **Proceedings of the 26th Annual Conference, American Association for Automotive Medicine**, 17-35, Ontario, Canada.

KAHANE, C.J. (1982). An evaluation of side structure improvements in response to Federal Motor Vehicle Safety Standard 214. Office of Program Evaluation, DOT HS 806314, Department of Transportation, National Highway Traffic Safety Administration Springfield, Virginia, USA.

KALLIERIS, D., MATTERN, R., McINTOSH, A. & BOGGASCH, F. (1992). The biofidelity of Eurosid I and Biosid. **Thirty-sixth Stapp Car Crash Conference Proceedings**, 103-117. SAE P-236, Soc. of Austomotive Engineers, Warrendale, PA.

KIUCHI, T., OGATA, K., WARNER, C.Y. & GORDON, J.J. (1991). Air bag systems for side occupant protection. Paper 91-S5-0-9, 13th Experimental Safety Vehicle Conference, France.

LAU, I.V. & VIANO, D.C. (1988). How and when blunt injury occurs - implications to frontal and side impact protection. **32nd STAPP Car Crash Conference Proceedings, P-215**, 81-100, SAE paper 881714. Society of Automotive Engineers. Warrendale, PA.

LAU. I.V., CAPP, J.P. & OBERMEYER, J.A. (1991). A comparison of frontal and side impacts: crash dynamics, countermeasures and subsystem tests, **Proceedings of the 35th STAPP Car Crash Conference, Vol. 35**, SAE P-251, pp109-124.

LESTINA, D., GLOYNS, P.F. & RATTENBURY, S.J. (1990). Fatally injured occupants in side impact crashes. Insurance Institute for Highway Safety, Arlington, VA.

LOW, T.C. & PRASAD, P. (1990) Dynamic response and mathematical model of the side impact dummy. **Thirty-fourth Stapp Car Crash Conference Proceedings**, 233-242. SAE P-236, Society of Automotive Engineers, Warrendale , PA.

MACKAY, M. (1988). Occupant protection and vehicle design. **Association for the Advancement of Automotive Medicine Course on the Biomechanics of Impact Trauma**, Los Angeles, USA.

MACKAY, M. (1990). Notes on a seminar. Monash Accident Research Centre and Royal Australasian College of Surgeons, 22 May, 1990. Melbourne, Vic., Australia.

MACKAY, G.M., HILL, J., PARKIN, S. & MUNNS, J.A.R. (1993). Restrained occupants on the non-struck side in lateral collisions. **Accident Analysis & Prevention**, 25(2), 147-152.

MACKAY, G.M., PARKIN, S., HILL, J. & MUNNS, J.A.R. (1991). Restrained occupants on the non-struck side in lateral collisions. **Thirty-fifth Annual Proceedings Association for the Advancement of Automotive Medicine**, 119-132.

MALLIARIS, A.C., HITCHCOCK, R. & HEDLUND, J. (1982). A search for priorities in crash protection. SAE International Congress & Exposition, SAE paper 820242. Society of Automotive Engineers Inc., Warrendale, PA, USA.

MARCUS, J.H., MORGAN, R.M., EPPINGER, R.H., KALLIERIS, D., MATTERN, R. & SCHMIDT, G. (1983). Human response to and injury from lateral impact. **Twenty-seventh STAPP Car Crash Conference Proceedings, P-134**, 419-432. SAE paper 831643. Society of Automotive Engineers Inc., Warrendale, PA.

MONASH UNIVERSITY ACCIDENT RESEARCH CENTRE (1992). Feasibility of occupant protection measures, Report CR 100. Federal Office of Road Safety, Department of Transport & Communications, Canberra, Australia.

OLSSON, J.A., SKOTTE, L-G. & SVENSSON, S-E. (1989). Air bag systems for side impact protection. **Twelfth International Technical Conference on Experimental Safety Vehicles, Proceedings**, Vol 2, 976-983.

OTTE, D. (1993). Deformation characteristics and occupant load capacity in lateral impacts for nearside belted front car passengers, **Thirty-seventh STAPP Car Crash Conference Proceedings, P-269**, 185-198, SAE paper 933126. Society of Automotive Engineers Inc., Warrendale, PA.

OTTE, D., SUREN, E.G., APPEL, H. & NEHMZOW, J. (1984). Vehicle parts causing injuries to front-seat car passengers in lateral impact. SAE paper 841651. Society of Automotive Engineers Inc., Warrendale, PA, USA.

OVE ARUP (1990). 1989 rural town restraint use survey, Report GR/90-4, VicRoads, Hawthorn, Victoria, Australia.

OZANNE-SMITH J. (1989). Evaluation of the effects of the Alfred Hospital Trauma Centre: Inter-rater reliability, Unpublished MPH Dissertation, Monash University Department of Social & Preventative Medicine, Melbourne, Australia.

PLANATH, I. (1993). Biomechanics and accident investigation in the development of car safety. **Crash Injury Biomehanics, Conference Proceedings**. Adelaide, NHMRC Road Accident Research Unit.

PREUSS, C.A. & WASKO, R.J. (1987). Results of MVMA sixteen full vehicle side impact tests using the proposed NHTSA test procedure. **SAE Transactions, 96**, 3.327-3.338, SAE paper 871115.

ROUHANA S.W. & FOSTER M.E. (1985). Lateral impact - an analysis of the statisticsin the NCSS, **Proceedings of the 25th STAPP Car Crash Conference, Vol 23**, (SAE Paper 892439), pp 79-98.

ROUHANA, S.W. & KROELL, C.K. (1989). The effect of door topography on abdominal injury in lateral impact. **33rd STAPP Car Crash Conference Proceedings**. 143-151, SAE paper 892433.

SCHULLER, E., BEIER, G. & STEIGER (1989). Injury patterns of restrained car occupants in near-side impacts. Side Impact:Injury Causation and Occcupant Protection, SAE SP-769, 1-5. Society of Automotive Engineers, Warrendale, PA.

SEGAL, D.J. (1983). Computer modelling of the side impact penetration of dummies of various sizes in padding. MGA Research Corp., DOT-HS-806,669. Dept. of Transportation, National Highway Traffic Safety Administration, Springfield, VA.

SHAIBANI, J.M. & BAUM, H.M. (1990) Comparisons od the Thoracic Trauma Index with other models. **Accident Analysis & Prevention**, 22, 35-45.

SHIMODA, N., NISHIDA, Y. & AKIYAMA, A. (1989). Effect of belt restraint systems on occupant protection performance in side impact crashes. **Twelfth International Conference on Experimental Safety Vehicles, Proceedings**, Vol 2, 963-968.

STROTHER, C.E., SMITH, G.C., JAMES, M.B. & WARNER, C.Y. (1984). Injury and intrusion in side impacts and rollovers. **Advances in Belt Restraint Systems: design, performance and usage. International Congress & Exposition, P-141**, 317-340. SAE paper 840403. Society of Automotive Engineers Inc., Warrendale, PA, USA.

THOMAS, P & BRADFORD, M. (1989). Side impact regulations how do they relate to real world accidents? **Twelfth International Technical Conference on Experimental safety Vehicles, Proceedngs**, Vol 2, 919-929.

TOMMASSONI, J.E. (1984). Simulation of a two-car oblique side impact using a simple crash analysis model. **Mathematical simulation of occupant and vehicle kinematics, P-146**, 23-50, SAE paper 840858.

TRANSPORT & COMMUNICATIONS (1988), **Road Crash Statistics**, Federal Office of Road Safety, Department of Transport & Communications, Canberra, Australia.

TRELLA, T.J., GABLER, H.C., KANIANTHRA, J.W. & WAGNER, J.J. (1991). Side impact crashworthiness design: evaluation of padding charateristics through mathematical simulations. SAE Technical Paper 912900, Society of Automotive Engineers, Warrendale , PA.

VIANO, D.C. (1987). A method to evaluate the benefit of energy-absorbing material for side impact protection. **Proceedings of the 1987 International IRCOBI Conference on Biomechanics of Impact**, 135-148.

VIANO, D.C. (1991). Evaluation of armrest loading in side impacts, **Proceedings of the 35th STAPP Car Crash Conference, Vol. 35**, SAE P-251, pp145-162.

VIANO, D.C. & LAU, I.V. (1985). Thoracic impact: a viscous tolerance criterion. **Tenth International Technical Conference on Experimental Safety Vehicles**, 104-114, Dept. of Transportation, National Highway Traffic Safety Administration.

VICROADS (1990). Incidental information provided to the authors on the incidence of seat belt wearing in the front and rear seating positions of Victorian motorists, VicRoads, Melbourne, Australia.

WARNER, C.Y., STROTHER, C.C., JAMES, M.B., STRUBLE, D.E. & EGBERT, T.P. (1989). Crash protection in near-side impact. Side Impact: Injury Causation & Occupant Protection, SAE SP-769, 85-101. Society of Automotive Engineers, Warrendale, PA.

WILLKE, D.T. & MONK, M.W. (1986). Side interior stiffness measurement. **30th STAPP Car Crash Conference Proceedings, P-189**, 81-98, SAE paper 861880. Society of Automotive Engineers, Warrendale, PA, USA.

ZHU, J.Y., CAVANAUGH, J.M. & KING, A.I. (1993). Pelvic biomechanic response and padding benefits in side impact based on cadaveric test series. **Thirty-seventh STAPP Car Crash Conference Proceedings, P-269**. 223-234, SAE paper 933128, Society of Automotive Engineers, Warrendale, PA, USA.

PASSENGER CARS AND
OCCUPANT INJURY

ATTACHMENTS

ATTACHMENT 1 .... Details of Inspection Procedure

ATTACHMENT 2 .... The Patient Injury Form

ATTACHMENT 3 .... The (NASS) Vehicle Inspection Forms

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.

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...................................

....

....

....

....

....

Monash University Accident Research Centre

PATIENT INJURIES

NO.	A.I.S.	SOURCE	FINAL DIAGNOSES

Monash University Accident Research Centre

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...

....

....

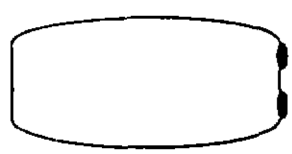
....

....

Crash Diagram

Estimated Impact Force

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



➡ Impact

☐ Damage

Rollover ☐

Patient

X Initial

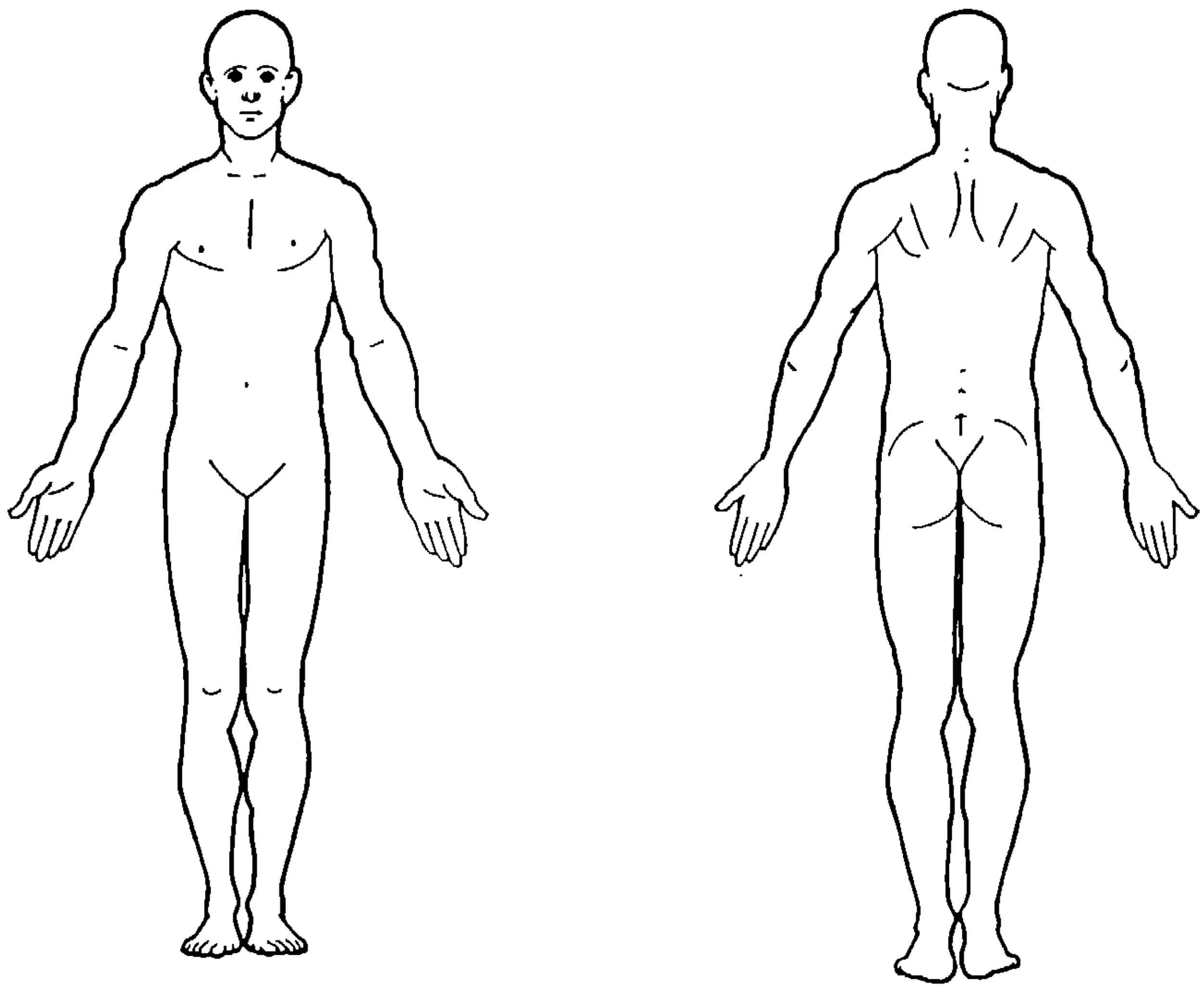
O On Arrival

Movement

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

OFFICIAL INJURY DATA—SOFT TISSUE INJURIES

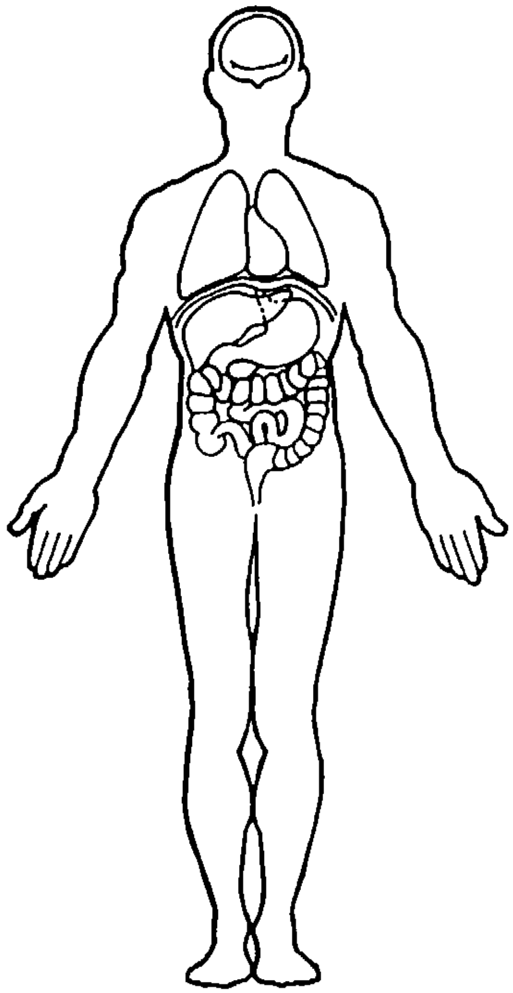
Indicate the *Location, Lesion, Detail* (size, depth, fracture type, head injury clinical signs and neurological deficits), and *Source* of all injuries indicated by official sources (or from PAR or other unofficial sources if medical records and interviewee data are unavailable.)

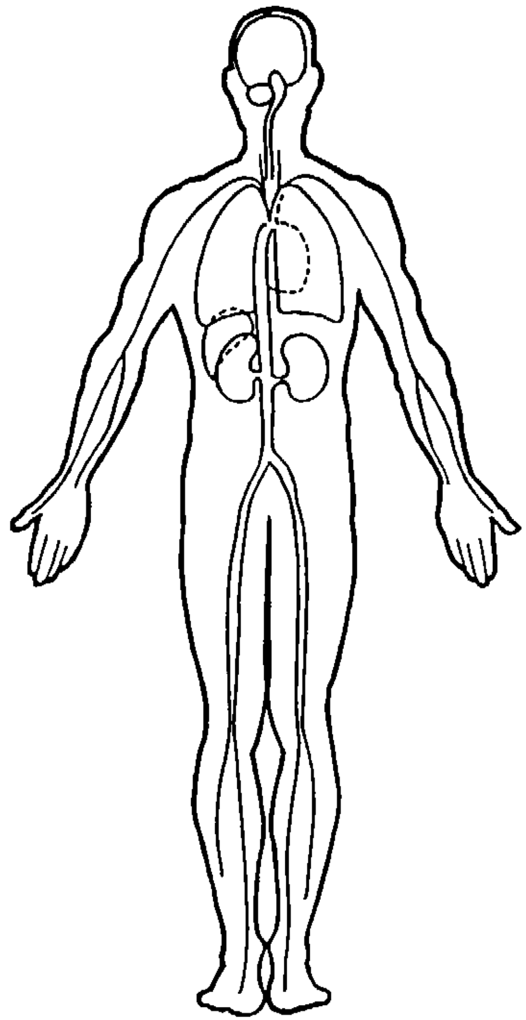


ATTACHMENT 2.

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.)

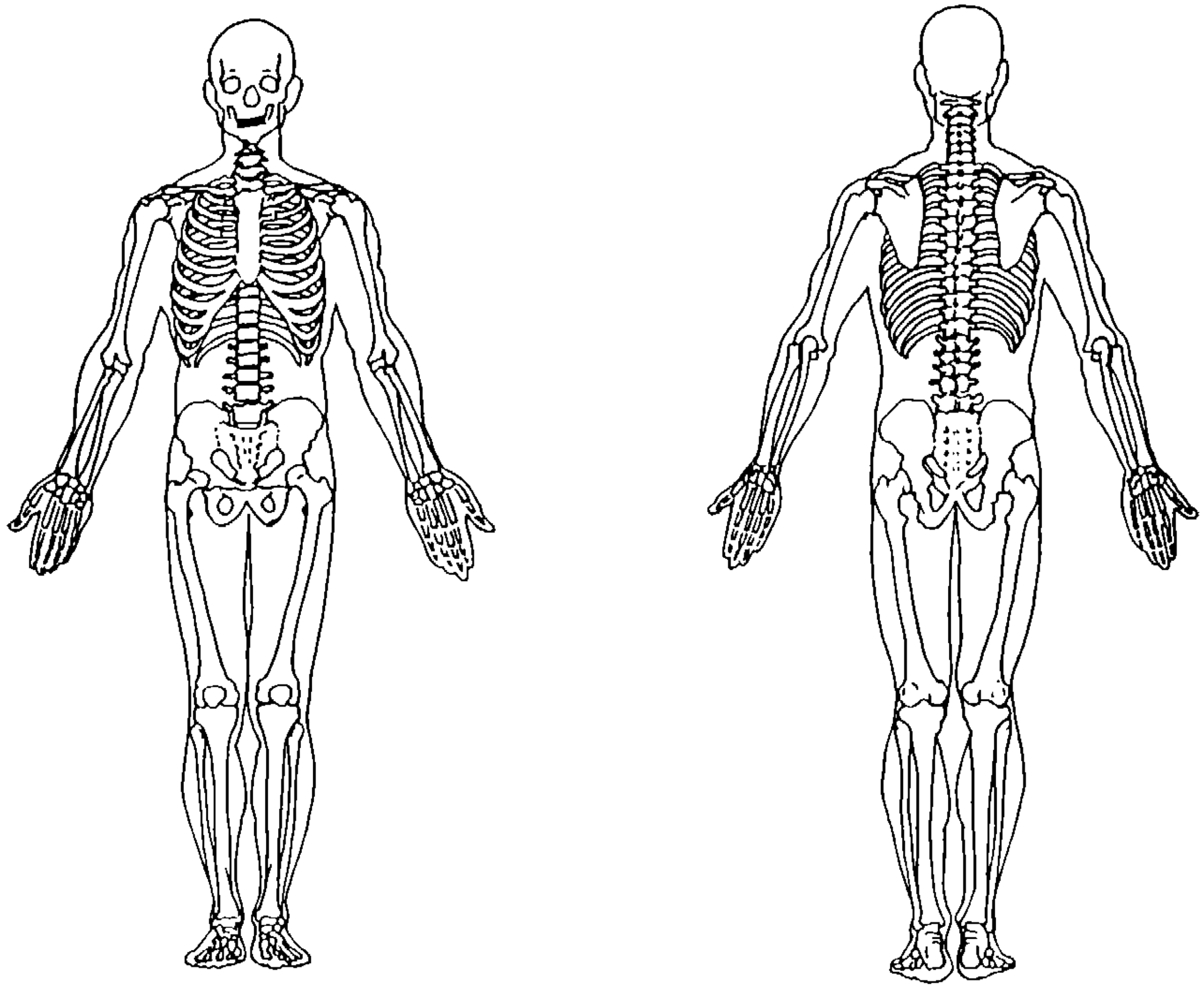




ATTACHMENT 2.

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

OCCUPANT INJURY FORM

CASE NUMBER ____________ PATIENT'S NAME ______________________________

HOSPITAL NUMBER ________________ UR NUMBER ________________________

INJURY DATA

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

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

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

SOURCE OF INJURY DATA

OFFICIAL

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

UNOFFICIAL

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

INJURY SOURCE

FRONT

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

LEFT SIDE

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

RIGHT SIDE

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

INTERIOR

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

ROOF

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

FLOOR

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

REAR

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

EXTERIOR OF OCCUPANT'S VEHICLE

- (55) Hood
- (66) Outside hardware (e.g., outside mirror, antenna)
- (67) Other exterior surface or tires (specify): ______
- (68) Unknown exterior objects

EXTERIOR OF OTHER MOTOR VEHICLE

- (70) Front bumper
- (71) Hood edge
- (72) Other front of vehicle (specify): ______
- (73) Hood
- (74) Hood ornament
- (75) Windshield, roof rail, A-pillar
- (76) Side surface
- (77) Side mirrors
- (78) Other side protrusions (specify): ______
- (79) Rear surface
- (80) Undercarriage
- (81) Tires and wheels
- (82) Other exterior of other motor vehicle (specify): ______
- (83) Unknown exterior of other motor vehicle

OTHER VEHICLE OR OBJECT IN THE ENVIRONMENT

- (84) Ground
- (85) Other vehicle or object (specify) ______
- (86) Unknown vehicle or object

NONCONTACT INJURY

- (90) Fire in vehicle
- (91) Flying glass
- (92) Other noncontact injury source (specify) ______
- (97) Injured, unknown source

INJURY SOURCE CONFIDENCE LEVEL

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

DIRECT/INDIRECT INJURY

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

OCCUPANT INJURY CLASSIFICATION

O.I.C. Body Region

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

Aspect of Injury

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

Lesion

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

System/Organ

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

ATTACHMENT 3.1

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 ******

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

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	________

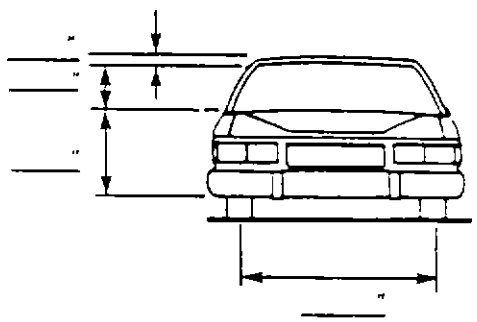
WHEEL STEER ANGLES
(For locked front wheels or displaced rear axles only)

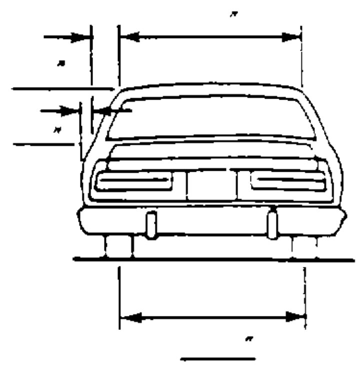
RF ± ____ °
LF ± ____ °
RR ± ____ °
LR ± ____ °
Within ±5 degrees

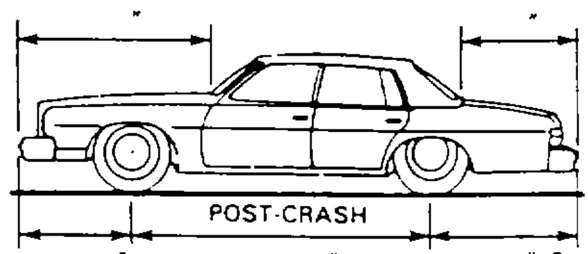
DRIVE WHEELS

☐ FWD ☐ RWD ☐ 4WD

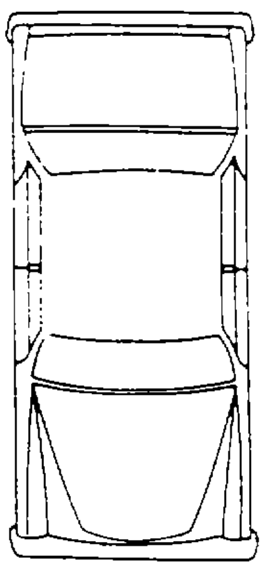
Approximate Cargo Weight ________

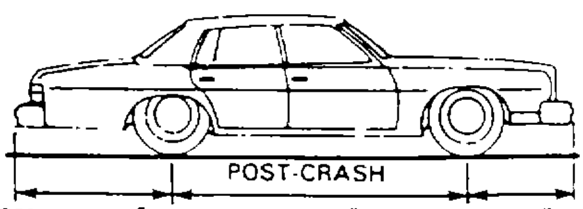






Bumper corner ____" ____" ____" Bumper corner
Stringline ____" ____" Stringline





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)

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

NATIONAL ACCIDENT SAMPLING SYSTEM
CRASHWORTHINESS DATA SYSTEM

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

National Accident Sampling System—Crashworthiness Data System:CrashPC Program Summary

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 __

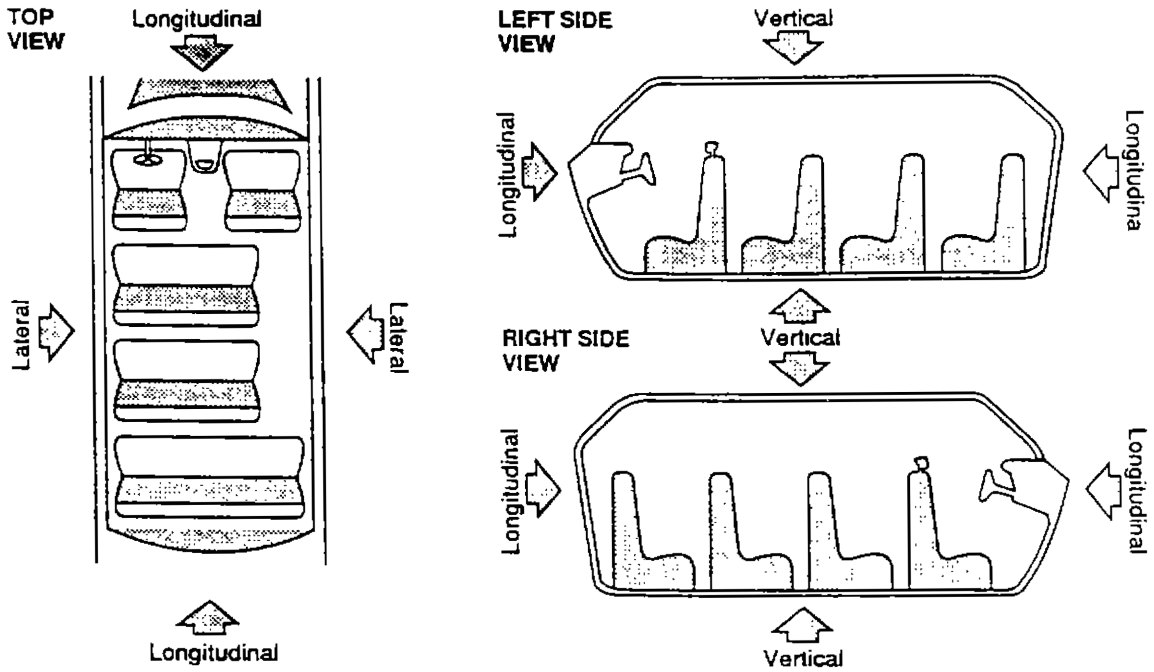
(0) No glazing contact and no damage, or no glazing
(1) AS-1 – Laminated
(2) AS-2 – Tempered
(3) AS-3 – Tempered-tinted
(4) AS-14 – Glass/Plastic
(8) Other (specify):
____
(9) Unknown

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

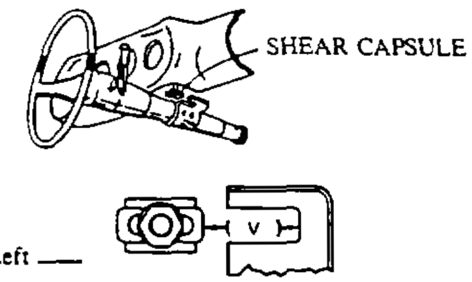
MAGNITUDE OF INTRUSION
- (1) $\geq$ 1 inch but < 3 inches
- (2) $\geq$ 3 inches but < 6 inches
- (3) $\geq$ 6 inches but < 12 inches
- (4) $\geq$ 12 inches but < 18 inches
- (5) $\geq$ 18 inches but < 24 inches
- (6) $\geq$ 24 inches
- (9) Unknown

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

STEERING COLUMN WORKING DIAGRAMS

STEERING COLUMN COLLAPSE

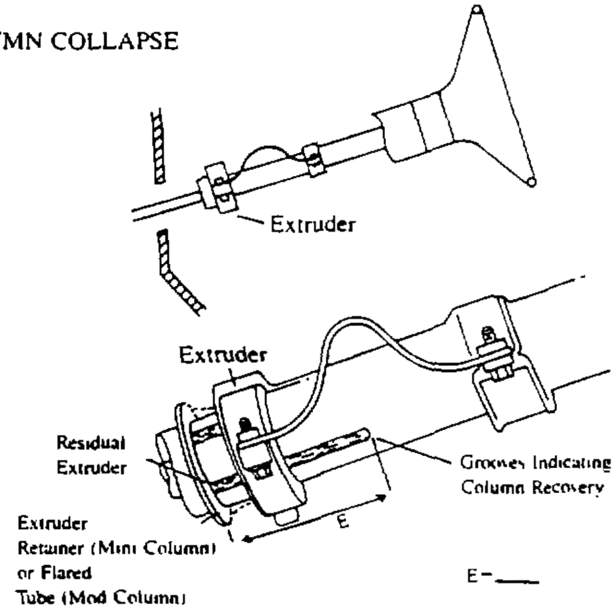
Steering Column Shear Module Movement



Left ___

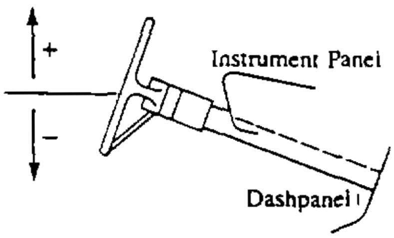
Right ___ V = ______"

Direction and Magnitude of Steering Column Movement

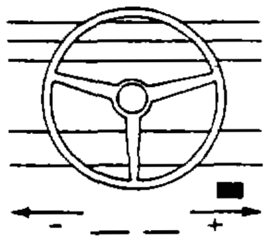


STEERING COLUMN MOVEMENT

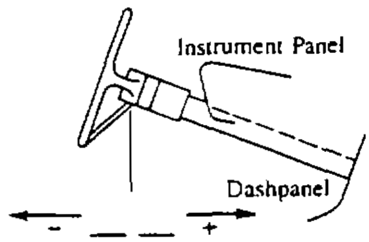
Vertical Movement



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.

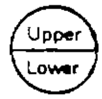
(0) No steering rim deformation
(1-5) Actual measured value
(6) 6 inches or more
(8) Observed deformation cannot be measured
(9) Unknown

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

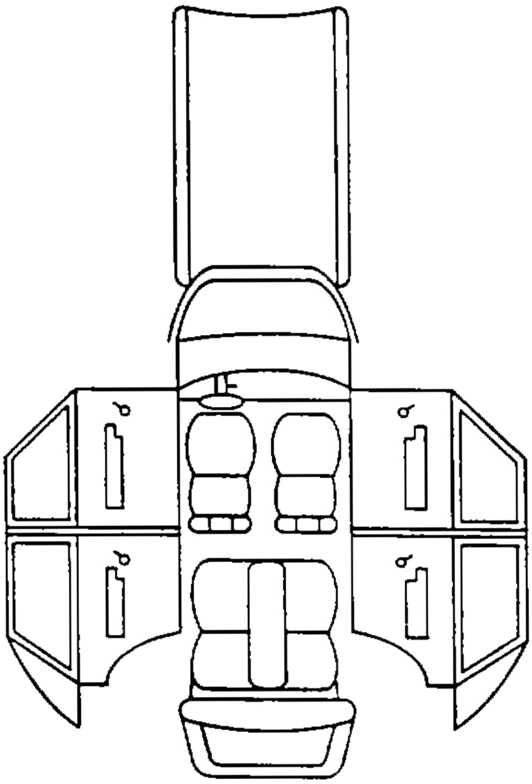
96. Knee Bolsters Deformed from Occupant Contact ___

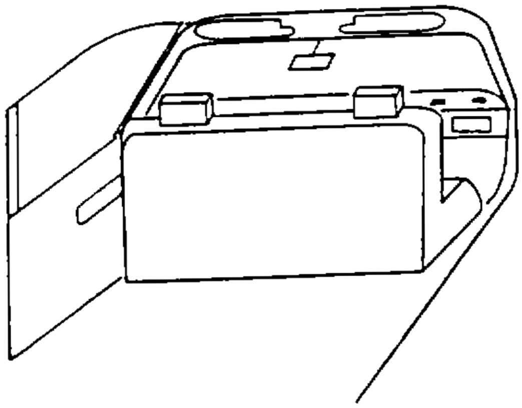
(0) No
(1) Yes
(8) Not present
(9) Unknown

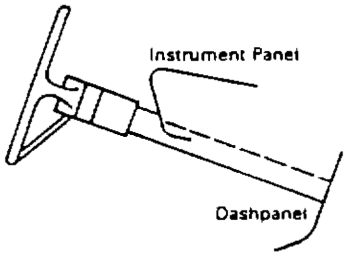
97. Did Glove Compartment Door Open During Collision(s) ___

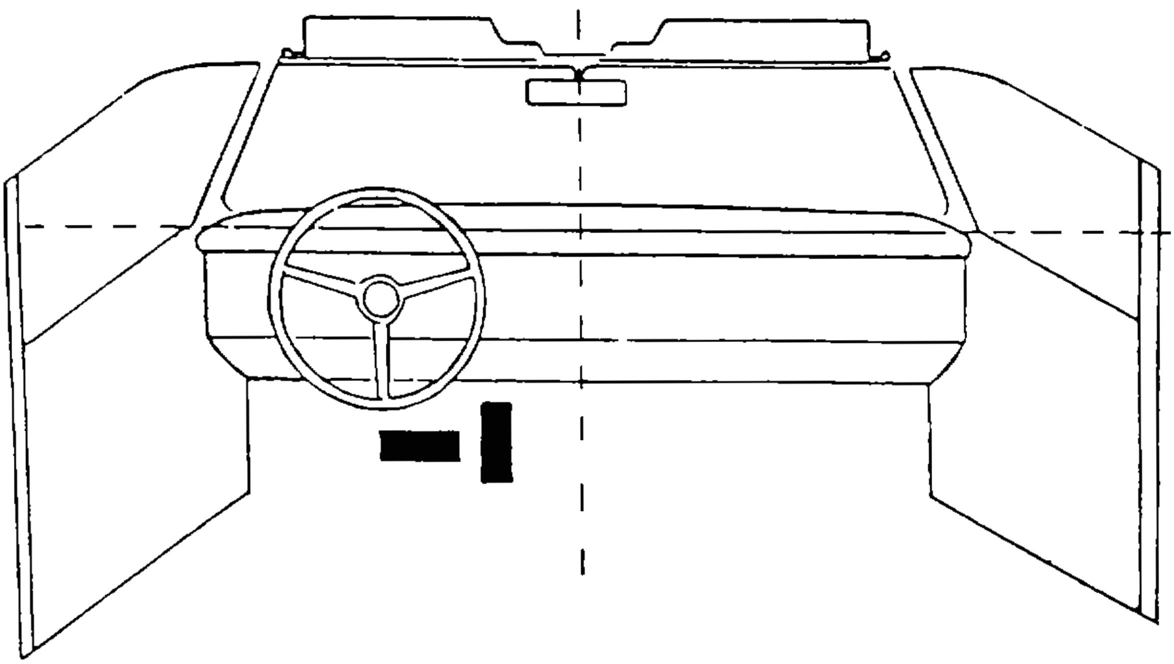
(0) No
(1) Yes
(8) Not present
(9) Unknown

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)