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Crashes Resulting in Car Occupant Fatalities: Frontal Impacts

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Abstract

This report describes crashes in which car occupants were killed as a result of frontal impacts. Frontal impacts account for just under half of road crashes in which car occupants are killed and in Australia over 500 persons were killed in 441 cars involved in fatal crashes in 1990. Various aspects of the crashes and the persons involved are presented for frontal crashes and compared between central (full frontal) and offset frontal impacts, as well as between driver's side offset and passenger's side offset frontal impacts.

Keywords

Fatal crashes, road crashes, frontal impacts

Notes

(1) FORS research reports are disseminated in the interests of information exchange.
(2) The views expressed are those of the authors and do not necessarily represent those of the Commonwealth Government.

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Executive summary

This report describes crashes in which car† occupants are killed as a result of frontal impacts. It is the first in a series which deals with different types of impacts resulting in car occupant fatalities.

Frontal impacts account for just under half (46%) of crashes in which car occupants are killed. In Australia in 1990 over 500 persons were killed in 441 cars involved in frontal crashes. In the majority of these collisions the impact was centrally located. The remainder of these frontal impacts (almost one third) were off centre with more of these offset crashes on the driver's side than the passenger's side.

Various aspects of the crashes and persons involved are presented for frontal crashes and compared between the central (full frontal) and offset frontal impacts, and also between driver's side offset and passenger's side offset frontal impacts.

Crash event

The majority of frontal car crashes (63%) involved the car colliding with another vehicle. The remainder (37%) were single vehicle crashes generally involving the car running into some fixed object.

The multiple vehicle crashes typically involved a collision with a larger vehicle; 54% were with trucks, buses, four wheel drive vehicles, vans or utilities, and a further 21% involved a collision with a car larger than the one sustaining the fatal frontal impact. Thus, in a total of 75% of multiple vehicle frontal crashes the car hit a vehicle with a larger mass. It is then not surprising that in 83% of cases where car occupants were killed in a collision with another vehicle, there were no fatalities in the other vehicle.

Although the tendency for multiple vehicle frontal crashes to involve collisions with heavier vehicles was observed in both urban and rural locations, a major difference is the proportion of these collisions with trucks. Whereas 37% of these collisions were with trucks in rural regions, the figure was 22% in urban locations.

The most common type of multiple vehicle crash was between vehicles travelling in opposing directions colliding head on. These head on crashes typically involved one vehicle straying into the wrong lane with only a relatively small number involving a deliberate manoeuvre, such as overtaking or turning at an intersection.

The single vehicle frontal impacts overwhelmingly involved the car losing control and leaving the carriageway (89%). Almost half of the single vehicle 'off-carriageway' events occurred on curved sections of road.

† The term *car* refers to sedans and stationwagons and excludes vans, 4WD and utilities.

Crash location and timing

Just over half of the frontal impacts occurred on roads in rural areas and just over half of these on National or State highways. Only a small number of the rural crashes occurred within intersections (7%) and even within urban areas the percentage of frontal crashes occurring within intersection was only 23%.

The crash sites were typically on straight sections of two-way undivided roads with unsealed shoulders. Driving conditions were generally good. Forty percent of the crashes occurred on weekends and just over half occurred in daylight.

Causal factors

There was evidence that alcohol contributed to 27% of the frontal impacts and in 86% of these cases it was the driver of the car with the occupant fatalities who was drunk. Intoxication contributed to a higher percentage of single vehicle frontal crashes than multiple vehicle frontal crashes.

Speeding contributed overall to 17% of frontal impacts, and, like alcohol, contributed to a higher percentage of single as opposed to multiple vehicle crashes. Taking into account the speed limit and the available information on whether the car drivers were speeding, resulted in the estimation that 59% of the cars were probably travelling at speeds of at least 100 kph before the crash and only about 17% were estimated to be travelling at or below 60 kph.

Overall, 11% of fatal frontal impacts were estimated to have involved loss of control on the left shoulder. This figure was 18% for crashes which occurred on roads with unsealed shoulders.

Persons involved

Almost three quarters of the drivers were male. Approximately half of the cars had passengers. The most common combination was a male driver and female passenger in the front seat (43%). In just under two thirds of the cars with front seat passengers, the passenger was within 5 years of the driver's age. The mean age of both the drivers and passengers was 38 years.

Approximately one fifth of the car occupants killed were not wearing seat belts.

Injury outcome

Three quarters of the car drivers involved in frontal impacts were killed, reflecting that the driver was often the sole occupant of the car. In the cars with both a driver and front left passenger, approximately half of the drivers and half of the front left passengers were killed.

Among the front seat occupants killed, the most common body regions sustaining severe injury were the head and chest. The occupants killed tended to have suffered multiple injuries often to different body regions. There was a higher percentage of severe head injuries among the younger driver and front passenger fatalities compared to those aged 60 or more.

The likelihood of being trapped or killed increased with the proximity of the impact; drivers were more likely to be killed in impacts offset on their side of the vehicle. Also, the percentage of rear seat passengers killed was much lower than the percentage of front seat passengers killed.

Full frontal versus offset frontal impacts

Offset impacts differed in a number of ways from centrally located impacts. The direction of force relative to the front bumper bar of the car differed between these two types of frontal crashes. Whereas almost all the full frontal impacts were perpendicular (ie. straight on), approximately half of the offset impacts were at an angle.

Another difference was the location of the crash. Although the majority of all frontal impacts were non-intersection crashes, there was a higher percentage of crashes occurring within intersections among the offset frontal impacts (20% vs 11%).

Driver's side versus passenger's side offset impacts

The greater number of cars with occupant fatalities resulting from frontal impacts offset on the driver's side (85) compared with the passenger's side (47) reflects mainly that there was a passenger sitting next to the driver in only half of the cars. However, there was still a slight asymmetry even after adjusting for occupancy. This is probably due to the fact that the predominant form of frontal crash (a head on crash with opposing traffic) is more likely to result in an impact offset on the driver's side rather than the passenger's side.

The major differences between driver's side and passenger's side offset impacts included:

- Passenger side offset impacts were more likely to be single vehicle crashes (40% vs 26%). This is also a reflection that head on multiple vehicle crashes less commonly impact on the passenger's side.

- Among the single vehicle frontal crashes, the passenger side impacts were more likely to result from a collision on the carriageway (26% vs 5%) than the driver's side impacts which more often involved a car running off the road into a tree. The objects hit on the carriageway included poles, signs and stationary vehicles.

- Deaths resulting from passenger's side offset impacts occurred less often in lighter cars (17% vs 39%). This is probably related to differences in occupancy, and driver and passenger characteristics in cars of different sizes.

- There was a higher percentage of unbelted occupant fatalities in frontal impacts offset on passenger's side than the driver's side.

Summary

Some of the issues that this paper draws attention to include:

Mass effects: Most fatal frontal impacts involve collisions with another vehicle and the overwhelming majority of these result from a collision with a vehicle of significantly greater mass.

Speed effects: Although data on actual impact speed was not available, it is instructive to note that only 17% of vehicles with occupant fatalities resulting from frontal impacts were estimated to be travelling at or below 60 kph prior to the crash.

Asymmetry of left and right offsets: The factors affecting occupant protection may differ for left and right frontal offset impacts. Differences were noted in belt use, crash type and vehicle size.

Acknowledgment

The authors wish to thank Mr Alan Jonas of the Vehicle Standards Section of the Federal Office of Road Safety for his many valuable comments during the production of this report.

1. Introduction

1.1 Objectives

This report describes crashes in which car occupants are killed as a result of impacts to the front of their vehicles. It is the first in a series which deals with different types of impacts resulting in car occupant fatalities. The other reports in the series will concentrate on side impacts and overturn crashes.

Various aspects of the crash, such as the pre-crash setting, the crash event, the vehicles and road users involved, and the injury outcome are detailed. Additionally, comparisons are made between different types of frontal impacts.

The major data source is the FORS* 1990 Fatality File database comprising all fatal road crashes reported to police in Australia in 1990. Comparisons are also made with a similar database from the United States of America (FARS** 1991 and 1992).

1.2 Report structure

Chapter 1 contains vehicle and impact definitions. More specific details with respect to the coding are found in the Appendix. The overall impact distribution is summarised for cars and other passenger vehicles and compared with equivalent US data.

Chapter 2 describes the frontal impacts in more detail and defines component subgroups. Further comparisons are made with the US data.

The pre-crash setting, crash event, occupant details and crash outcome are summarised for frontal crashes in Chapter 3 and these characteristics are compared between full frontal impacts and offset frontal impacts in Chapter 4. The report concludes with a summary chapter.

1.3 Definitions

Cars

The definition of car used in this report includes sedans, coupes, station wagons, hatchbacks, sports cars and convertibles. Panel vans and utilities based on a car design (namely, Ford and Holden) and other larger passenger vehicles, such as passenger vans, four wheel drive vehicles and light trucks are excluded from the primary analyses in this report. The occupants of cars (thus defined) comprise 50% of all road users killed in Australia in 1990.

In terms of vehicle numbers, cars make up 57% of vehicles involved in fatal crashes. The other larger passenger vehicles (vans, 4WD etc) comprise a further 16% of vehicles involved (Table 1).

* FORS Federal Office of Road Safety, Australia
** FARS Federal Accident Reporting System, US

This report concentrates on cars with occupant fatalities. In 989 of the 1657 cars involved in fatal crashes at least one occupant was killed (Table 1). Cars comprise 80% of passenger vehicles with occupant fatalities (989 out of 1233).

Table 1. Number and percentage of different types of vehicles involved in fatal crashes in Australia 1990 by whether or not occupants were killed (Source: FORS 1990 Fatality File)

Vehicle type	Number of occupant/rider fatalities: No fatalities		At least one fatality		Total vehicles in fatal crashes	
Two wheel						
MC/moped	23	2%	248	15%	271	9%
Bicycle	2	0%	80	5%	82	3%
Passenger vehicles						
Car*	**668**	**53%**	**989**	**59%**	**1657**	**57%**
Utility	54	4%	77	5%	131	4%
4WD	58	5%	55	3%	113	4%
Passenger van	48	4%	37	2%	85	3%
Car-based utility	38	3%	44	3%	82	3%
Panel van	16	1%	23	1%	39	1%
Light truck	10	1%	8	0%	18	1%
Heavy vehicles						
Articulated truck	167	13%	56	3%	223	8%
Rigid truck	118	9%	26	2%	144	5%
Bus	22	2%	7	0%	29	1%
Other/unknown	32	3%	13	1%	45	2%
Total	1256	100%	1663	100%	2919	100%

* The primary vehicle type studied

Impact types

Vehicles with occupant fatalities were initially classified into broad impact groups (front, side, overturn, other) based on the location of the impact most likely to have caused the fatality. The small number of cases (14 cars) where the fatality was not impact related (such as falling from the vehicle or drowning) or where the location of the impact was unknown were excluded.

Fatality file data (Australia)

For the Australian data, the groups were derived from the *point* of primary impact and *direction* of primary impact items in the 1990 Fatality File database (Figures A1 A2 and Table A1 in the Appendix).

Frontal impacts include both broad frontal impacts and impacts to any part of the front of the vehicle, both perpendicular to the front and at oblique angles. Corner impacts with direction of impact from the front or at an angle (but not the side) are also included (Figure A2, Appendix)

Frontal impacts are further divided into central and offset impacts according to whether the whole or centre of the front of the vehicle is damaged or only one side is damaged. These three types of frontal impacts are termed full frontal (FF), front left (passenger's side) offset (FL) and front right (driver's side) offset (FR) impacts (Figure A2, Appendix).

FARS data (US)

The Fatal Accident Reporting System (FARS) contains detailed crash, vehicle and personal information on fatal road crashes in the United States.

The impact groups were defined on the basis of two items; the *most harmful event* and the *principal point of impact*. The most harmful event item was used to distinguish cases where the fatalities occurred as a result of overturns as opposed to other types of non-collisions (such as falling from the vehicle, immersion, fire/explosion) and from collisions with vehicles or other objects. In a second step, the principal point of impact item was used to divide up the fatal collisions according to the impact point on the vehicle. Thus, cases in which an overturn occurred after a collision were classified into the overturn impact category only if this was considered to be the most harmful event, ie. the fatality occurred during the overturn. As with the Australian data, fatalities occurring as a result of falling from the vehicle or immersion were excluded.

The principal point of impact variable is coded according to a clock face with 12 o'clock being an impact to the front of the vehicle and 6 o'clock an impact to the rear of the vehicle.

Remembering that the steering wheel is on the left hand side of vehicles in the States, impacts at 11, 12 and 1 o'clock were defined as front driver's side offset, full frontal and front passenger's side offset impacts, respectively, and collectively defined as frontal impacts.

1.4 Overall impact distribution

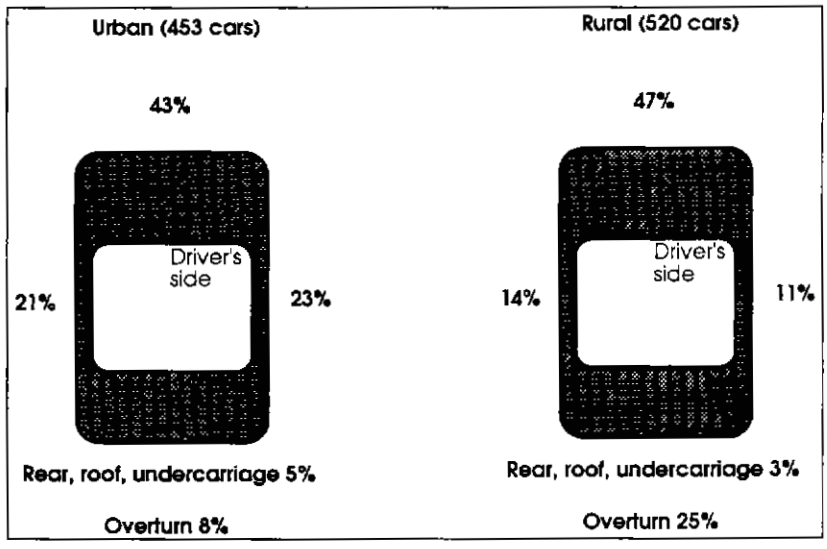
Passenger vehicles

The overall impact distribution for cars and other passenger vehicles involved in fatal crashes in 1990 in Australia in which at least one occupant dies as a result of the impact or overturn is shown in Table 2. The front of the vehicle is the most common fatal impact location for cars (45%). The percentages of fatal impacts occurring on the right, on the left and as a result of overturns were all 17%. The remaining 4% comprise impacts at the rear, on the roof and undercarriage (Table 2). The impact distribution is shown for urban and rural areas separately in Figure 1. Urban areas have a higher percentage of side impacts whereas rural areas have a markedly higher overturn rate and a slightly higher percentage of frontal impacts.

Table 2. *Number and percentage of passenger vehicles with at least one occupant fatality by fatal impact location on the vehicle and vehicle type (FORS 1990 Fatality File)*

Fatal impact area	Passenger cars		Vans, 4WD, utilities, light trucks	
Front	441	45%	106	45%
Right (driver's) side	163	17%	18	8%
Left side	170	17%	11	5%
Other (rear, roof, undercarriage)	38	4%	4	2%
Overturn	163	17%	94	40%
Total vehicles	975	100%	233	100%

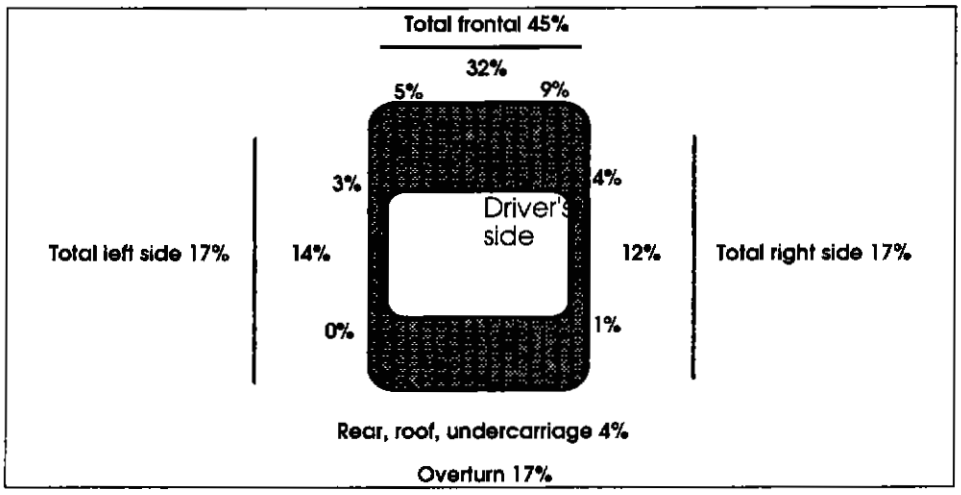
Figure 1 *Frontal impact distribution for cars with occupant fatalities in urban and rural areas of Australia (1990 Fatality File)*



Among larger passenger vehicles (vans, four wheel drive vehicles, utilities and light trucks), there are proportionally fewer side impacts and a higher percentage of overturns compared with cars. The percentage of overturns also differs within the group of larger passenger vehicles; 62% for four-wheel drive vehicles compared with 34% for vans, utilities and light trucks. Four wheel drive vehicles also have the lowest percentage of frontal impacts (25%) compared with the other passenger vehicles (51%).

The impact distribution for the 975 cars is illustrated in more detail in Figure 2. This figure shows the broad impact locations broken down into the components. For example, the frontal impacts represent 45% overall and this is made up of 32% full frontal impacts (FF), 9% front right offset impacts (FR) and 5% front left offset impacts (FL).

Figure 2. *Percentage distribution of fatal impact locations on 975 cars with at least one occupant fatality in the 1990 Fatality File*



Impact distribution relative to occupancy

It should be noted that the fatal impact distribution is dependent on many factors and one of these is the seating position of the vehicle occupants. The predominance of frontal impacts is clearly related to the fact that each of the cars has a driver, but not necessarily any passengers in the back seat. Even though, overall, there were approximately equally many fatal impacts on the driver's side and the passenger's side of the cars, the passenger's side is not always occupied. In fact, the front left passenger seat was occupied in only 52% of the 975 cars. So, the equal left-right fatal impact distribution is not indicative of equal numbers of impacts on each side. In fact, the lower occupancy rate on the left is compatible with a greater number of potentially fatal impacts on the passenger's side relative to the driver's side.

A simple way to partly control for the left-right imbalance in occupancy is to restrict the comparison to symmetric seating combinations, ie. cars with either both a driver and a front left passenger only, or cars with a driver and a front left passenger and passengers on the right and the left in the rear of the vehicle. This selection results in 366 cars out of the 975 and, of these, 57 of the fatal impacts were on the driver's side and 85 were on the passenger's side. The crude ratio of passenger's side to driver's side fatal impacts is greater than one (approximately 1.5). However, many other factors, such as the sex, age and seat belt status of the drivers and passengers may affect the potential lethality of the impact.

These issues will be dealt with the second report in this series. Only frontal impacts are considered in detail in this report; with left and right side crashes in the second and overturn crashes in the third in the series. Similar considerations are also relevant in assessing the distribution of left and right offset impacts among the frontal crashes (9% driver's side offset vs 5% passenger's side offset in Figure 2). These are dealt with in the next chapter.

International comparison

The overall impact distribution and percentage of overturns for cars with occupant fatalities in Australia (1990) is similar to that observed in the US (Table 3 and Figure 3) in both 1991 and 1992.

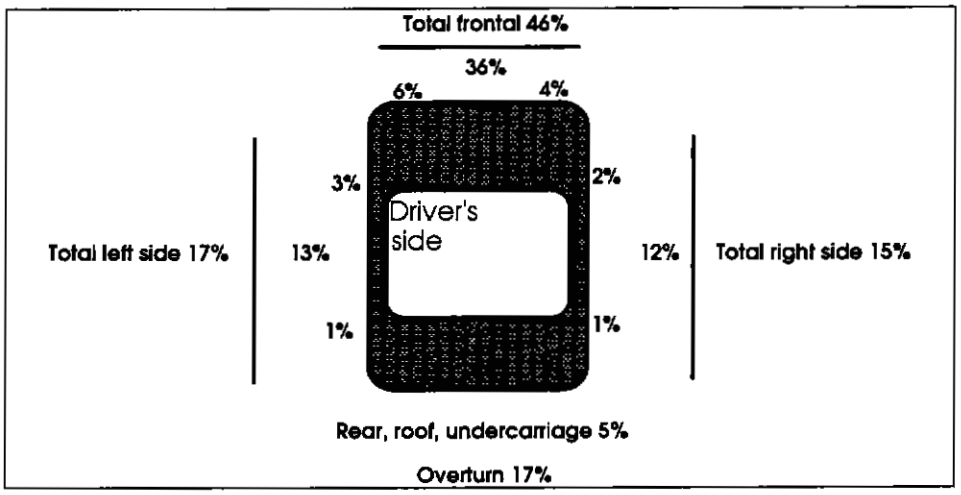
The occupancy rate for the front passenger seat (47% in both 1991 and 1992) is slightly less than that observed in the Australian data (52% in 1990). Also, the passenger to driver's side ratio of fatal impacts for cars with symmetric seating combinations is greater than unity (1.3), but smaller than the 1.5 observed in the Australian data. This is consistent with a paper by Evans and Frick[1] based on earlier FARS data which reported 38% more impacts of high severity on the passenger's side compared to the driver's side based on front seat occupant deaths. These comparisons will be considered further in the side impacts report, the second in this series.

The US data has a smaller proportion of offset frontal impacts (10% US vs 14% in Australia). The ratio of driver's side to passenger's side frontal offset impacts is less pronounced in the US (6% vs 4%) than in Australia (9% vs 5%). These differences are addressed in detail in the next chapter.

Table 3. Number and percentage of cars with at least one occupant fatality by fatal impact location on the vehicle in Australian fatal crashes (FORS 1990) and US fatal crashes (FARS 1991 and 1992)

	Australia		US			
Fatal impact area	1990		1991		1992	
Front	441	45%	8678	46%	8443	46%
Driver's side	163	17%	3198	17%	3069	17%
Passenger's side	170	17%	2885	15%	2806	15%
Other (rear, roof, undercarriage)	38	4%	910	5%	855	5%
Overturn	163	17%	3282	17%	3000	17%
Total vehicles	975	100%	18953	100%	18173	100%

Figure 3. *Percentage distribution of fatal impact locations on 18173 cars with at least one occupant fatality in the US FARS database 1992. (The distribution for 1991 is similar).*



2. Frontal impacts description

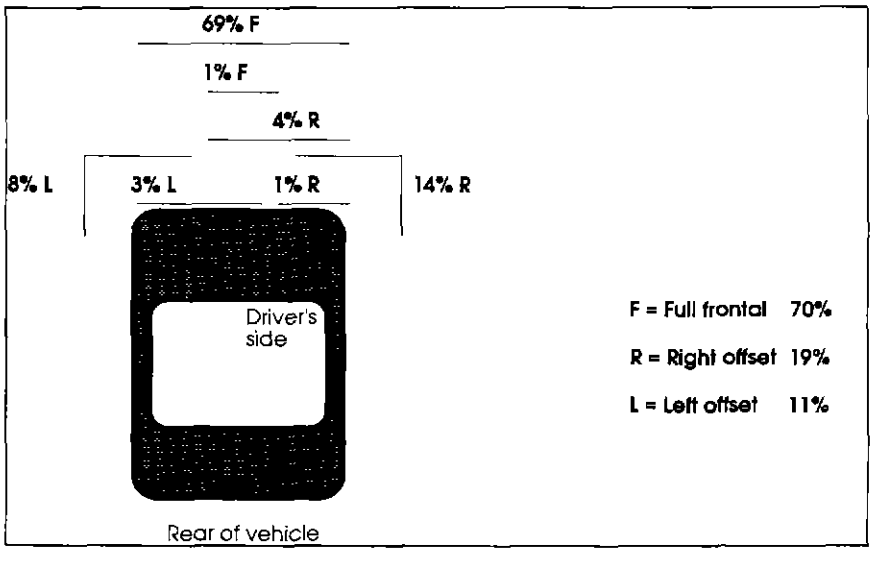
This chapter describes the different types of frontal impacts in terms of the area of damage and the direction of impact for the 441 cars with at least one occupant fatality. Further comparisons are made with the FARS data from the US.

2.1 Frontal impact distribution

In the 1990 Fatality File the area of damage to the front of the vehicle is coded in detail. This is illustrated in Figure 4 and Figure A1 in the Appendix. The length of the lines in Figure 4 indicate the range of damage to the vehicle. For example, in 69% of cars with frontal impacts there is damage to the whole of the front of the vehicle, whereas in only 1% there is damage to the central portion only. A further 4% of frontal impacts result in damage to both the centre and right of centre at the front of the vehicle.

The 'L' shaped lines indicate cases where there is either a diagonal impact to the corner of the car which continues to impact both sides, or there is damage on both the front and side and the actual point of impact is not clear (Figure 4). Impacts coded as the L shape, but for which the direction of impact is from the side, are not included as frontal impacts and have been excluded. These impacts are classified as side impacts. The only L shaped impacts included as frontal impacts are those for which the direction is from the front or at an oblique angle. See the Appendix for details.

Figure 4. *Percentage distribution of area of impact for 441 passenger cars sustaining frontal impacts causing at least one occupant fatality (FORS 1990 Fatality File)*



As mentioned earlier, frontal impacts are subdivided into full frontal, right and left offset according to the area of the damage. These three groups are labelled F, R and L on Figure 4. Front right offset impacts will also be referred to as driver's side offset impacts and front left offset impacts will also be referred to as passenger's side offset impacts for the remainder of this report.

For the 441 cars sustaining fatal frontal impacts in 1990, the percentage breakdown between full frontal, right and left offset impacts is 70%, 19% and 11%, respectively (Figure 4). Full frontal impacts include mainly cases where there is damage to the whole of the front of the vehicle. They also include a small number of cases (5) where there is damage to the central portion only. Driver's side offset impacts comprise mainly the L shaped impacts to the front right corner of the car and the passenger's side offset impacts comprise mainly the L shaped impacts to the front left corner of the car (Figure 4).

Some analysis of other similar data suggests that there may be some misclassification of the point of impact when there is insufficient detail in the case files (such as no photo of the vehicle). It appears that this leads to a slight underestimation of driver's side impacts and a corresponding overestimation of full frontal impacts, but does not affect the number of passenger's side offset impacts. It is estimated that the true percentage of full frontal impacts may be in the vicinity of 66% and driver's side impacts 23%, rather than the 70% and 19% observed in the 1990 Fatality File. However, an error of this magnitude doesn't change the basic findings that central crashes predominate and that driver's side impacts outnumber passenger's side impacts.

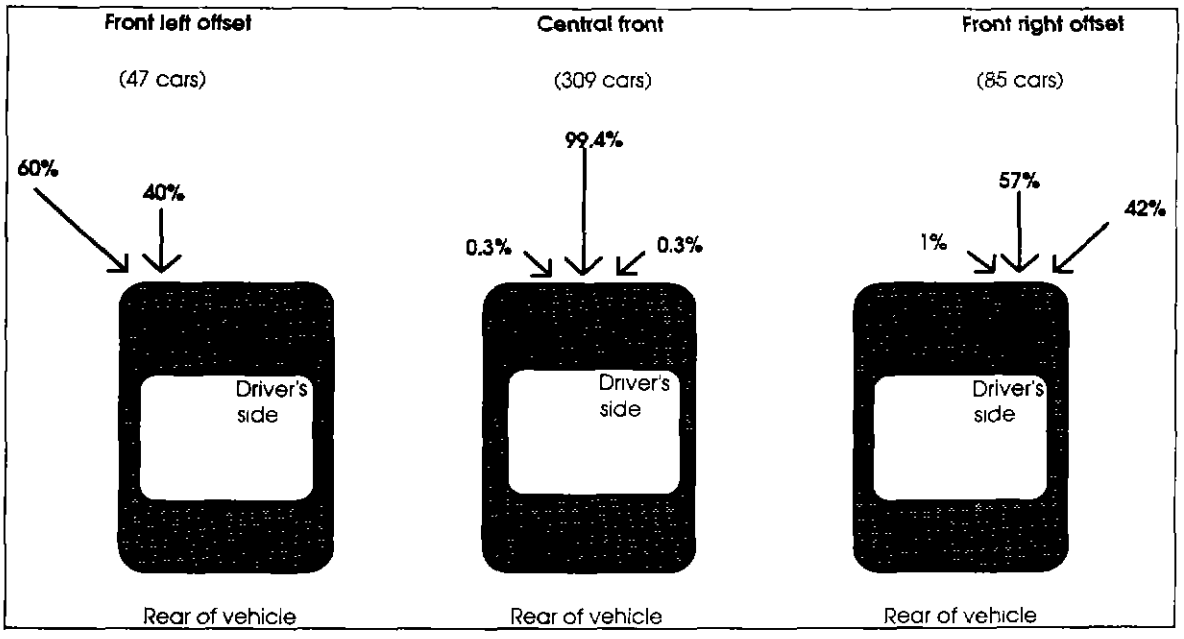
The imbalance between right and left reflects that the driver's seat is almost always occupied, but there may not always be a front left passenger. Restricting the comparison to cars with both a driver and front left seat passenger, the breakdown for the observed 1990 Fatality File data is 66%, 18% and 16% for full frontal, driver's side offset and passenger's side offset (219 cars). So there are still slightly more fatal offset impacts on the driver's side compared with the passenger's side even when there are at least two persons in the front seat.

Direction of impact

Figure 4 shows the percentage breakdown within the full frontal and the offset crashes with respect to the direction of impact. Almost all of the full frontal impacts (99%) were at right angles to the front of the vehicle. Only 2 (1%) were at an angle.

There were higher percentages of oblique impacts for the offset crashes compared with the full frontal collisions (Figure 5). The perpendicular versus oblique breakdown differed for the driver's and passenger's side offset impacts, however, with a higher percentage of perpendicular impacts offset on the driver's side (57% at right angles vs 42% at oblique angles) and a lower percentage of perpendicular impacts offset on the passenger's side (40% vs 60%) (Figure 5).

Figure 5. *Percentage distribution of direction of impact for front left offset, central front and front right offset impacts for a total of 441 cars (FORS 1990 Fatality File)*



The same overall pattern in the direction of impact was observed for the different types of frontal impacts both for cars with a driver only (Figure 6), and cars with a driver and front left passenger (Figure 7). However, the difference in the perpendicular to angular ratio between the offset crashes was more pronounced in the cars without a front left passenger (Figure 6) than in the cars with both a driver and a front left passenger (Figure 7). For example, 10 of the 12 (83%) far side offset impacts to the cars with a driver only were angular and only 2 (17%) were straight on, compared with a more even breakdown (18 and 17) in the 35 cars with left offset impacts containing at least 2 persons in the front seat.

Figure 6. *Percentage distribution of direction of impact for front left offset, central front and front right offset impacts for a total of 220 cars with a driver but no front left passenger (FORS 1990 Fatality File)*

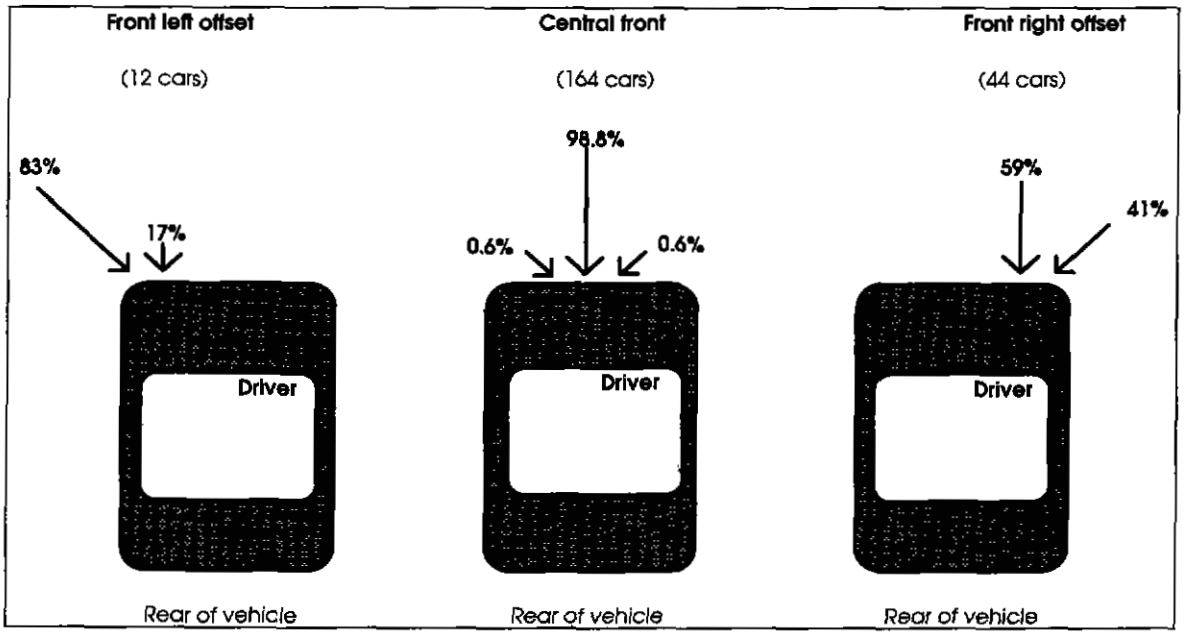
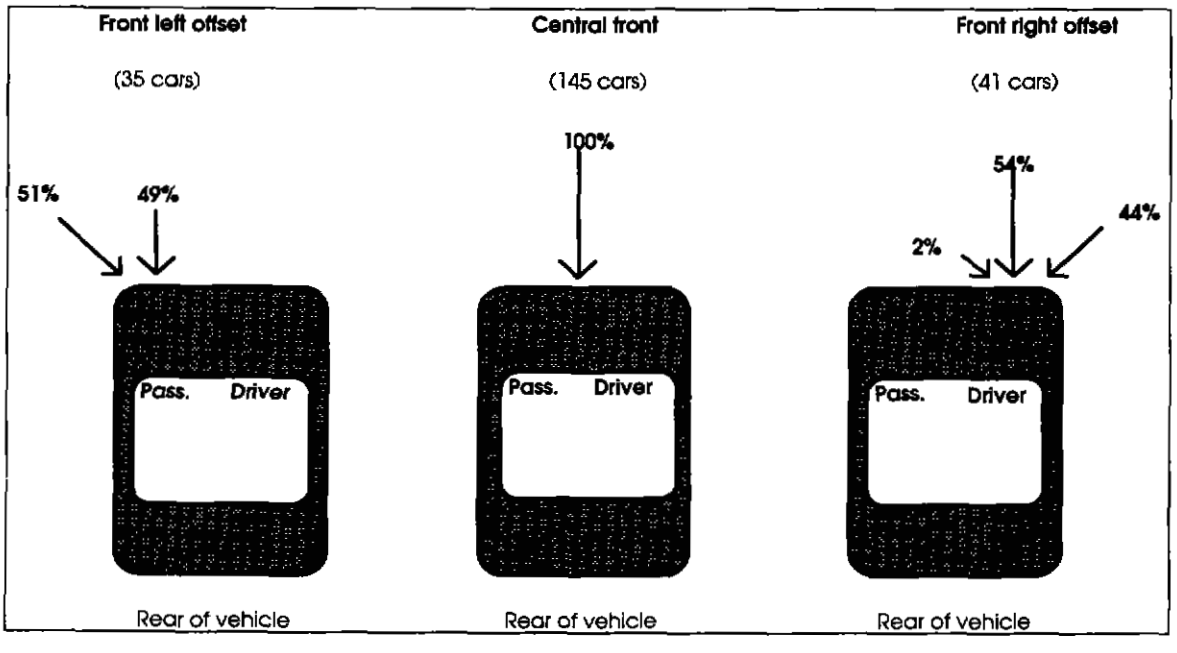


Figure 7. *Percentage distribution of direction of impact for front left offset, central front and front right offset impacts for a total of 221 cars with both a driver and a front left passenger (FORS 1990 Fatality File)*



2.2 International comparison (FARS)

Impact distribution

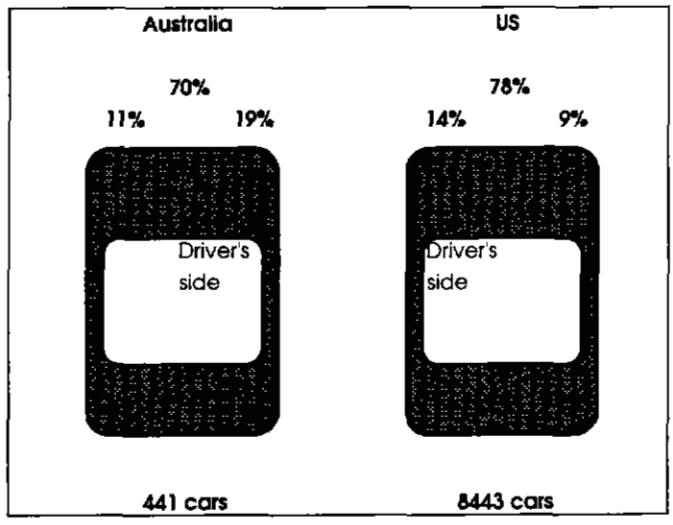
The overall proportion of fatal impacts which are frontal is similar for cars in Australia and the US (Table 3). Remembering that the driver is on the left hand side in the US, the 11 o'clock, 12 o'clock and 1 o'clock frontal impacts in the US data approximate the driver's side offset, full frontal and passenger's side offset crashes for Australia (Figure 8). The same overall pattern is observed with full frontal crashes predominating and, within the offset impacts, more on the driver's side. However, there do appear to be fewer offset crashes, in general, in the US data compared to the Australian data.

Restricting the comparison to cars with a driver *and* front seat passenger, the breakdown for Australia is 66%, 18% and 16% for full frontal, driver's side offset and passenger's side offset (219 cars). The corresponding figures for the US are 76%, 13% and 11% for 3641 cars sustaining fatal frontal impacts in 1991. So, in both databases there are still 2% more fatal driver's side offset impacts than passenger's side offset impacts, even when there is a passenger present.

There is still a smaller percentage of offset crashes in the US data even after adjusting for occupancy. Closer inspection of the clock face diagram used to distinguish the offset (11 and 1 o'clock) impacts from the full frontal (12 o'clock impacts) shows that this could be a result of slightly different coding delineation. The 12 o'clock impacts include almost all of the front of the vehicle whereas the 11 and 1 o'clock areas include only the corners and the front wheel areas. Crashes with the point of impact off centre on the front of the vehicle (codes 18 and 20 in the Australian Fatality File database, Appendix Figure A1) would probably be coded as 12 o'clock impacts under the American system, but are coded as offset impacts in this report. If these impacts (32 cars) are added to the full frontal impact group in the Australian data, the resulting breakdown is 77% full frontal, 15% on the driver's side and 8% on the passenger's side. These percentages are all within 1% of the FARS breakdown in Figure 8.

It should be noted that the FARS database does not have a separate item detailing the direction of impact.

Figure 8. *Comparison of the frontal impact distribution for cars with occupant fatalities in Australia (1990 Fatality File) and the US (FARS 1991). Frontal impacts are divided into full frontal, driver's side and passenger's side offset impacts. (The US distribution for 1992 is similar to 1991, but not shown.)*



3. Characterisation of frontal impact crashes

This chapter describes the pre-crash setting, the vehicle characteristics, the car occupant characteristics and the injury outcome for drivers and passengers involved in fatal frontal impacts. Unless specified otherwise, the term *passenger* will generally refer to passengers sitting in the front on the left hand side. Both full and offset frontal impacts are considered in this chapter. These impacts types will be compared in a later chapter (Chapter 4).

3.1 Pre-crash setting

Fatality file

The location, road configuration and driving conditions are summarised for fatal frontal impact crashes in Tables 4 and 5. The tabulation of the pre-crash setting characteristics for the 441 cars sustaining fatal frontal impacts involves some double counting, since some of the cars are involved in the same crash. The 441 cars were involved in 422 separate crashes. Nineteen of the crashes thus involved two cars colliding head on and resulting in at least one fatality in each car. This represents 5% of the crashes and is not considered large enough to distort the overall pattern.

Fatal frontal impact crashes are slightly more likely to occur in rural locations than urban areas (Table 4). Of the rural crashes, just over half occurred on National or State Highways. It follows that the speed zone is likely to be at least 100 kph. The road configuration is generally undivided and the road shoulder is unsealed. Only 7% of fatal impacts within rural areas occurred within intersections.

Just over 70% of the urban frontal crashes occurred in the metropolitan areas of the capital cities. Twenty-three percent of these crashes occurred within intersections.

As with fatal crashes in general, the road at the crash site was generally straight and level and driving conditions tended to be good. Frontal impacts are also similar to other fatal crashes in terms when they occurred; with 55% during daylight hours and, overall, 60% occurring on weekdays (Table 5).

US comparison

A comparison can be made between the Australian and US data for those crash setting characteristics recorded in both fatal crash databases (Tables 4 and 5). The percentage estimates for the US data are based on almost 20 times the numbers in Australia.

Table 4. *Location and road type for 441 cars sustaining frontal impacts resulting in at least one occupant fatality (FORS 1990 Fatality File). Percentages are also shown for cars involved in similarly defined crashes in the US (FARS 1991, 8678 cars; 1992, 8443 cars). Shaded areas indicate percentages calculated on subsets of the data.*

	Australia 1990		US 1991	US 1992
Pre-crash characteristics	Cars	%	%	%
Location				
Urban	196	44%	41%	40%
Rural	245	56%	59%	60%
Urban location				
Capital city metropolitan area	139	71%	-	-
Other urban locaiton	57	29%	-	-
Rural road type				
National/State highway	134	55%	70%	71%
Other rural road	111	45%	30%	29%
Speed limit				
<= 60 kph (<= 40 mph)	119	27%	28%	29%
65-95 kph (45-50 mph)	68	15%	17%	19%
100 kph (55 mph)	210	48%	50%	48%
110 kph (60-65 mph)	43	10%	5%	4%
Location with respect to intersection				
Non-intersection	380	86%	83%	82%
Intersection	61	14%	17%	18%
Urban locations				
Non-intersection	151	77%	78%	76%
Intersection	45	23%	22%	24%
Rural locations				
Non-interseciton	229	93%	87%	87%
Intersection	16	7%	13%	13%
Road type for *non-intersection* crashes				
Undivided	331	87%	76%	77%
Divided	48	13%	24%	23%
Intersection configuration for *intersection* crashes				
X intersection	33	54%	-	-
Y or T intersection	28	46%	-	-
Road shoulder				
Unsealed	206	66%	-	-
Sealed	106	34%	-	-

Table 5. *Driving conditions for 441 cars sustaining frontal impacts resulting in at least one occupant fatality (FORS 1990 Fatality File). Percentages are also shown for cars involved in similarly defined crashes in the US (FARS 8678 cars, 1991; 8443 cars, 1992). The shaded area indicates percentages calculated on subsets of the data.*

	Australia 1990		US 1991	US 1992
Pre-crash characteristics	Cars	%	%	%
Horizontal road alignment				
Straight	282	**64%**	**74%**	**73%**
Curve	158	36%	26%	27%
Vertical road alignment				
Level	319	**74%**	**70%**	**68%**
Other	112	26%	30%	32%
Road conditions				
Dry	359	**82%**	**80%**	**79%**
Wet	81	18%	20%	21%
Weather				
Fine	379	**86%**	**86%**	**84%**
Inclement	61	14%	14%	16%
Time of week				
Weekday	266	**60%**	**64%**	**65%**
Weekend	175	40%	36%	35%
Time of day				
Day	242	**55%**	**50%**	**50%**
Dawn/dusk	12	3%	4%	4%
Night	187	42%	47%	46%
Street lighting for *night* time crashes				
On	76	**43%**	**34%**	**35%**
Off/none	102	**57%**	**66%**	**65%**

The percentage of frontal impacts occurring in rural areas is slightly greater in the US. Within rural crashes, there is a higher percentage of US crashes occurring on State Highways compared with other rural roads and the percentage of intersection crashes in rural areas is higher in the US compared with Australia. Of the non-intersection crashes, the percentage occurring on undivided roads is higher in Australia. Also, the percentage of US crashes occurring on straight sections of road is higher than the corresponding percentage in Australia.

In Australia, there is a higher proportion of crashes occurring in either natural or artificial light.

These differences may well result from slight differences in coding (ie. the definition of rural or intersection). The higher US proportions of impacts on straight sections of road and on divided roads may also just reflect the overall differences between roads in the two countries (ie. the US has more divided roads than Australia), and not necessarily crash related factors.

3.2 Crash event

The crash event characteristics for the 441 cars sustaining fatal frontal impacts are summarised in the following tables (Tables 6, 8 and 7).

Most crashes resulting in fatal frontal impacts comprise a single collision with either a vehicle or object. Only 11% involve a series of events. Most of the multiple events involve a series of collisions (non-fatal, then fatal) and only five of the 48 multiple event crashes involve a prior avoidance manoeuvre and then a fatal collision.

Just under two thirds (63%) involve more than one moving vehicle, but in the remaining 37% the car runs into a fixed or non-fixed object (Table 6). By way of comparison, the corresponding US proportion of multiple vehicle frontal impacts is similar (61% in 1991).

Overall, in 11% of the frontal impacts, the car lost control on the left hand side shoulder of the road before the collision. Restricting the comparison to roads with unsealed shoulders, the percentage with causal involvement of the shoulder is 18%.

Table 6. Distribution of crash-event characteristics for 441 cars sustaining frontal impacts resulting in at least one occupant fatality (FORS 1990 Fatality File)

Crash event characteristics	n	%
Total	441	100%
Complexity of crash		
Single event (single collision with vehicle or object)	392	**89%**
Multiple event (prior avoidance manoeuvre or collision & subsequent fatal collision)	48	11%
Number of moving vehicles involved in the crash		
Multiple vehicle	277	**63%**
Single vehicle*	164	37%
Vehicle lost control on left shoulder		
No	392	**89%**
Yes	47	11%

Multiple vehicle crashes

Of the 441 cars sustaining fatal frontal impacts in 1990, 227 (63%) were involved in multiple vehicle crashes. Just over half of these occurred in rural locations. Approximately half of the frontal multiple vehicle collisions were with other cars (46%), but the other half were with larger vehicles (buses, trucks, four wheel drive vehicles and vans). Of the 127 collisions with another car, 58 were with cars of a heavier weight class (Table 7). Thus, only 25% of crashes were with lighter or comparable vehicles and 75% were with vehicles heavier than the car with the occupant fatalities.

* The 164 single vehicle crashes are defined as collisions with objects and this includes 11 cases where the object is a parked vehicle.

This breakdown was also carried out for urban and rural crashes separately. As expected, the percentage of collisions with cars was higher in urban regions (51%) compared with rural regions (42%), and the percentage of collisions with buses and trucks was lower in urban regions (22%) compared with rural regions (37%). However, when the weight of the cars was taken into account, the percentage of collisions with vehicles of heavier mass were not strikingly different (urban 73% and rural 77%). It is interesting to note the relatively high percentage of multiple vehicle frontal impacts in urban locations with heavy vehicles (22%) all of which were trucks (both rigid and articulated).

Table 7. Distribution of crash event characteristics for 277 cars involved in multiple vehicle crashes sustaining frontal impacts resulting in at least one occupant fatality (FORS 1990 Fatality File)

Crash event characteristics for multiple vehicle crashes	n	%
Total	277	100%
Location		
Rural	156	**56%**
Urban	121	44%
Type of other vehicle involved in fatal impact with car		
Car	127	**46%**
Car of *lighter* weight class* than car with frontal impact and fatalities	(31)	(11%)
Car of *same* weight class as car with frontal impact and fatalities	(38)	(14%)
Car of *heavier* weight class than car with frontal impact and fatalities	(58)	(21%)
Bus/truck	85	31%
Four wheel drive vehicle	25	9%
Ute/light truck	14	5%
Car-based utility	10	4%
Forward control passenger van	9	3%
Panel van	7	2%
Impact point on other vehicle		
Front	228	**82%**
Rear	18	6%
Right (driver's side)	18	6%
Left (passenger's side)	10	4%
Overturn	3	1%
Crash type according to relative direction of vehicles involved in fatal impact		
Vehicles from opposing directions	228	**82%**
Head on, neither vehicle turning/overtaking	(202)	(73%)
Head on involving overtaking	(14)	(5%)
Other (at least one vehicle turning)	(12)	(4%)
Vehicles from adjacent directions	23	8%
Other (includes lost control after collision)	14	5%
Vehicles from same direction (includes rear end crashes)	12	4%

* Weight determined by make and model and categorised into 3 classes: light <1100 kg, medium 1100-1300 kg and heavy >1300 kg

A high percentage (82%) of the multiple vehicle impacts were head on collisions between vehicles travelling in opposite directions (ie. the impact point on the other vehicle was also the front) (Table 7). Of these 228 head to head collisions, only 14 involved one vehicle overtaking another.

Eighteen of the multiple vehicle collisions involved the car running into the rear of another vehicle. These 18 other vehicles included 4 cars, 6 vans, utes or light trucks, 5 rigid trucks and 3 articulated trucks.

Single vehicle crashes

Single vehicle crashes comprised 37% of fatal, frontal impacts in 1990 (164 cars). As with multiple vehicle frontal impacts, just over half of these occurred in rural locations. In most of the single vehicle crashes, the driver lost control of the car and it left the carriageway. There were similar proportions of drivers losing control on straight and curved sections of the road. It was coded that the car lost control on the left shoulder of the road in 37 cases (23%). Restricting this to roads with unpaved shoulders, the percentage with causal involvement of the left shoulder is 38% (28 out of 77).

The commonest objects hit were trees (49%) (Table 8). There were 11 cases in which the car ran into a parked vehicle (4 articulated trucks, 3 rigid trucks, 1 bus, 1 light truck and 2 cars). In all but one of these collisions, the car ran into the rear of the stationary vehicle.

Table 8. Distribution of crash-event characteristics for 164 cars involved in single vehicle crashes sustaining frontal impacts resulting in at least one occupant fatality (FORS 1990 Fatality File)

Crash event characteristics for single car crashes	n	%
Total	164	100%
Location		
Rural	89	**54%**
Urban	75	46%
Object hit in a single car crash		
Tree	80	**49%**
Pole	29	18%
Sign/rail	18	11%
Support/culvert	13	8%
Other (eg. animal, fence, road works materials)	13	8%
Parked vehicle	11	7%
Crash type		
Car lost control and left carriageway on straight section	76	**46%**
Car lost control and left carriageway on curved section	71	**43%**
Other, (eg. ran into parked vehicle or object on carriageway)	17	11%
Causal involvement of left shoulder		
No	126	**77%**
Yes	37	23%

Vehicle body

The cars sustaining fatal, frontal impacts are typically sedans. Approximately one third weigh less than 1100 kg (Table 9).

Table 9. Distribution of vehicle characteristics for 441 cars sustaining frontal impacts resulting in at least one occupant fatality (FORS 1990 Fatality File)

Vehicle characteristics	n	%
Total	441	100%
Body type		
Sedan	344	**78%**
Stationwagon/hatchback	96	22%
Convertible	1	0%
Approximate weight class of car (based on average weight of different models and makes)		
Light (<1100 kg)	149	34%
Medium (1100-1300 kg)	167	**38%**
Heavy (>1300 kg)	125	28%

Speed

For approximately 73% of the cars, there was no evidence of speeding. Nineteen percent were coded as definitely speeding and 8% probably speeding. This information is combined with the speed limit at the crash site to form a crude estimate of the speed of the vehicle (Table 10, see footnote for details).

Almost 60% of the cars sustaining fatal, frontal impacts were probably travelling at speeds of at least 100 kph. Only 17% of cars were travelling at speeds of 60 kph or less.

Table 10 also shows the speed estimates separately for cars involved in single vehicle crashes and cars involved in a frontal collision with another moving vehicle. The major difference between the estimated speeds of the cars involved in single and multiple vehicle collisions is that there are more cars travelling at slower speeds involved in the multiple vehicle impacts. This probably reflects that more of the cars involved in multiple vehicle crashes are turning or pausing at intersections. It should be noted that whether or not the other# vehicle in a multiple vehicle crash is speeding and also its direction of travel have both been ignored in the estimations.

Table 10. Distribution of speed estimates for 440 cars sustaining frontal impacts resulting in at least one car occupant fatality by crash type (FORS 1990 Fatality File) (Note that these estimates are based on the car only; the speed and orientation of the other vehicle relative to the car in a multiple vehicle crash are ignored.)

	Single vehicle		Multiple vehicle		All frontal	
	n	%	n	%	n	%
Total frontal impacts	164	100%	276	100%	440	100%
Estimated speed* of car						
<60 kph	1	1%	16	6%	17	4%
60 kph	18	11%	38	14%	56	13%
65-80 kph	19	12%	42	15%	61	14%
85-95 kph	32	19%	15	5%	47	11%
100 kph	60	**37%**	115	**42%**	175	**40%**
110 kph	16	10%	29	10%	45	10%
>110 kph	18	11%	21	8%	39	9%

The 'other' vehicle is the one which collides with the front the car causing the death of at least one of the car occupants.

*The speed of the car is estimated crudely from the speed limit at the crash site, the vehicle movement prior to the crash and whether the vehicle was coded as *unlikely* to be speeding, *probably* speeding or *definitely* speeding (including cases where excessive speed is a major causal factor). If the speed category was not noted and speed was not a causal factor, the car was assumed to be travelling at the speed limit. Seven categories are distinguished. The general rule used was that the car moved up one speed class if *probably* speeding and moved up two classes if coded as *definitely* speeding:

1. <60 :not speeding in <60 zone or stopped, turning or manoeuvring in any speed zone
2. 60 :not speeding in 60 zone or probably speeding in <60 zone
3. 65-80:not speeding in 65-80 zone or probably speeding in 60 zone or definitely speeding in <60 zone
4. 85-95:not speeding in 85-95 zone or probably speeding in 65-80 zone or definitely speeding in 60 zone
5. 100 :not speeding in 100 zone or probably speeding in 85-95 zone or definitely speeding in 65-80 zone
6. 110 :not speeding in 110 zone or probably speeding in 100 zone or definitely speeding in 85-95 zone
7. >110 :probably or definitely speeding in 110 zone or definitely speeding in 100 zone

Causal factors

On the basis of the coroner's report, up to three major causal factors are coded for each crash in the 1990 Fatality File. The incidence of specific factors, such as alcohol intoxication, speeding and fatigue, are tabulated below for drivers involved in fatal frontal impact crashes. The factors are tabulated separately for drivers involved in single and multiple vehicle crashes. For the multiple vehicle crashes, the drivers of the cars sustaining the frontal impacts are distinguished from the other drivers involved in the crash (Table 11).

Overall, alcohol intoxication causally contributed to 27% (120) of the fatal, frontal impacts. The percentage is highest for the single vehicle crashes (40%, 65 out of 164 car drivers) compared with the multiple vehicle crashes (22%, 55 out of 277 crashes). In 38 of the 55 cases of drunk driving causing the multiple vehicle impact, the driver of the car sustaining the fatal frontal impact was drunk and in 18 of these cases the other driver was drunk. In one impact, both the car driver and the other driver were drunk. Thus, overall, in 86% of crashes where alcohol was causally implicated (103/120), it was the driver of the car sustaining the fatal frontal impact who was drunk (Table 11).

Excessive speed contributed to 17% of fatal frontal impacts. Speeding was also more likely in the single vehicle crashes than in the multiple vehicle crashes (26% vs 12%).

Fatigue was noted as contributing to 13% of fatal, frontal impacts. However, of the total of 58 fatigue related impacts, only 21 were definite cases of fatigue or falling asleep at the wheel (ie. generally with witness statements). The other 37 cases were coded as *possibly* asleep or fatigued related.

In 13 (3%) of the crashes, vehicle defects contributed to the crash. In 7 of these cases, the defect was detected in the car which sustained the frontal impact (2% of 441). These 7 defects include 2 tyre blowouts, one other tyre defect, 2 brake problems and 2 other unspecified defects.

Despite the high degree of detail in the Fatality File, in 34% of the 441 frontal impacts, the road user action which caused the crash was unexplained. The corresponding percentages for single vehicle and multiple vehicle frontal impacts were 26% and 39%, respectively.

In summary, risk taking, such as intoxication or other voluntary risk taking behaviour, contributed causally to one third (33%) of the fatal frontal impacts. This percentage was as high as 50% for the single vehicle crashes, compared with 22% for the multiple vehicle impacts. There remain, however, a large number of fatal crashes which are unexplained, especially among the multiple vehicle impacts.

Table 11. Incidence of causal factors related to drivers of 441 cars sustaining frontal impacts resulting in at least one occupant fatality and other road users involved in these crashes (FORS 1990 Fatality File). Percentages do not sum to 100% since up to three causal factors may be coded for a single crash.

	Single vehicle		Multiple vehicle impact				Total	
	Car driver Frontal impact		Car driver Frontal impact		Other driver		All road users	
Causal factor	n	%	n	%	n	%	n	%
Total frontal impacts	164	100%	277	100%	277	100%	441	100%
Alcohol (with or without other drugs)	65	40%	38	14%	18	6%	120	27%
Voluntary risky actions	44	27%	35	13%	20	7%	96	22%
Excessive speed	42	26%	25	9%	11	4%	76	17%
Fatigue	28	17%	23	8%	7	3%	58	13%
Possible	16	10%	17	6%	4	2%	37	8%
Definite	12	7%	6	2%	3	1%	21	5%
Driver error	14	9%	17	6%	18	6%	48	11%
Inattention, failure to observe other roaduser or signal	10	6%	6	2%	8	3%	24	5%
Critical vehicle malfunction	3	2%	4	1%	6	2%	13	3%
Unexplained action	43	26%	67	24%	41	15%	152	34%

Driver characteristics

Almost three quarters of the drivers of cars sustaining fatal, frontal impacts were male. Approximately one third were under 25 years of age, but 20% were aged over 60 (Table 12). The mean age of the driver was 38.

Sixteen percent of the drivers were not wearing seat belts, assuming that in those cases in which there was no information, the driver was probably restrained.

Also, assuming those drivers not tested for blood alcohol content (BAC) were not drunk, approximately one quarter of all the drivers of cars sustaining fatal frontal impacts were over the legal limit for BAC.

Table 12. Distribution of characteristics of 439 drivers of cars sustaining frontal impacts resulting in at least one occupant fatality (FORS 1990 Fatality File)*

Driver characteristics	n	%
Total	439	100%
Sex		
Male	314	**72%**
Female	125	28%
Age group		
<25	154	**35%**
25-29	47	11%
30-39	71	16%
40-49	47	11%
50-59	29	7%
60+	89	20%
Seat belt use		
Worn	290	**66%**
Not stated	79	18%
Not worn	70	16%
Blood alcohol content (BAC)		
Not tested	88	22%
Zero	202	**51%**
0.01-0.05 gm/100 ml	11	3%
>0.05 gm/100 ml	97	24%

* For two cars with fatal frontal impacts, the driver was not able to be distinguished from the front left passenger. These vehicles are excluded from analyses of driver and passenger characteristics. In each of these cases, one of the front seat occupants died and the other was hospitalised.

The employment status and occupation of 73% of the drivers was recorded in the Fatality File database. Of those for which information was available, 6% were unemployed. The breakdown for males and females is shown in Table 13. The most common occupational groups among the males were tradesmen/labourers and retirees, whereas females were most likely to be in the clerical, sales and service sector or at home.

Table 13. Occupational status of 322 male and female drivers of cars sustaining frontal impacts resulting in at least one occupant fatality (FORS 1990 Fatality File)

	Male drivers		Female drivers	
Occupational status	n	%	n	%
Tradesperson/labourer	76	**33.6%**	10	10.4%
Retired/pensioner	55	**24.3%**	16	16.7%
Manager/administrator/professional/ para-professional	39	17.3%	11	11.5%
Unemployed	17	7.5%	3	3.1%
Clerical/sales/service	16	7.1%	25	**26.0%**
Student	12	5.3%	9	9.4%
Other (including other employed and military service)	11	4.9%	2	2.1%
Household duties	0	0.0%	20	**20.8%**
Total	226	100%	96	100%

Seating positions of occupants

Just over half of the cars involved in fatal frontal impacts (57%) contained passengers as well as a driver (Table 14). Twenty-five percent of all the cars had 3 or more occupants. Male drivers were somewhat more likely to be carrying passengers (61%) than female drivers (47%). The mean age of the drivers carrying passengers was the same as the mean age of the drivers travelling alone (38 years).

Half of the cars had a passenger in the front left passenger seat. The front centre position was rarely occupied. One quarter of the cars had rear seat passengers, but only 3% of cars had rear seat passengers and no front passengers.

The most common seating combinations were driver only (43%), then driver and front left passenger only (28%), followed by various combinations of driver, front left passenger and rear passengers (19%) (Table 14).

Table 14. Seating positions of occupants of 441 of cars sustaining frontal impacts resulting in at least one occupant fatality (FORS 1990 Fatality File)

Occupant details	n	%
Total cars	441	100%
Number of car occupants		
1 (driver only)	189	**43%**
2	141	32%
3	55	12%
4	33	8%
5 or more	23	5%
Presence of passengers in cars driven by males		
No, male driver only	123	39%
Yes	191	**61%**
Presence of passengers in cars driven by females		
No, female driver only	66	53%
Yes	59	**47%**
Presence of a front left passenger		
No	222	50%
Yes	219	50%
Number of front seat occupants		
1	201	**46%**
2	221	50%
3	5	1%
Unknown	14	3%
Presence of rear passengers		
No	320	**73%**
Yes, at least one	109	25%
Unknown	12	2%
Most frequent seating combinations		
Driver only	189	**43%**
Driver and front left passenger only	125	28%
Driver, front left and single rear seat passenger only	46	10%
Driver, front left, and two rear passengers only	25	6%
Driver, front left and three or four rear passengers only	12	3%
Driver and rear passengers only	12	3%
Other (including some positions unspecified)	32	7%

Front left passengers

A total of 219 (50%) of the cars sustaining fatal, frontal impacts had a passenger sitting in the front left seat (Table 15). Just over half of these passengers were female. All these vehicles also had a driver. The most common combination was a male driver and a female passenger (43%) followed by a male driver and a male passenger (34%, Table 15).

Only 7% of the front left passengers were children (under 17 years of age). Forty-three percent of the passengers were within 2 years of the age of the driver. The mean difference in the ages of the driver and the passenger sitting next to them was not statistically significantly different from zero; the mean age for both the driver and passenger was 38 years. The consistency of the ages was observed both for cars driven by males and cars driven by females, and also, specifically, for the 95 male drivers with female passengers.

The percentage of unrestrained passengers is approximately the same as for drivers, assuming those for which no information is given are restrained (Tables 12 and 15). Restricting the comparison to the 219 drivers of cars which also have passengers, 13% of these drivers were not wearing seat belts compared with 16% of their passengers. In 16 of the cars which contained both a driver and a passenger, neither the driver nor passenger was restrained. However, seat belt status was not recorded for either the driver, the passenger or both in a high percentage of cars (21%, 47 cars) (Table 15).

Table 15. Distribution of characteristics of front left passengers in 219 of cars sustaining frontal impacts resulting in at least one occupant fatality (FORS 1990 Fatality File)

Front left passenger characteristics	n	%
Total cars with a front left passenger	219	100%
Sex of front left passenger		
Male	98	**45%**
Female	121	55%
Sex of front left (FL) passenger relative to driver		
Male driver, female FL passenger	95	**43%**
Male driver, male FL passenger	74	34%
Female driver, female FL passenger	26	12%
Female driver, male FL passenger	24	11%
Age of front left passenger		
<5	2	1%
5-16	12	6%
17-24	83	**39%**
25-59	61	29%
60+	55	26%
Age of front left passenger relative to driver		
Within 2 years	90	43%
Within 5 years	134	64%
Within 10 years	169	80%
Seat belt/restraint use of front left passenger		
Worn	151	**69%**
Not stated	34	15.5%
Not worn	34	15.5%
Seat belt/restraint use of driver and FL passenger		
Both restrained	135	62%
Neither restrained	16	7%
Only driver restrained	12	6%
Only front left passenger restrained	9	4%
Either or both unknown	47	21%

3.3 Crash outcome

Number of fatalities

A total of 528 persons were killed in the cars sustaining fatal frontal impacts. In the vast majority of these crashes, there was only one car occupant killed (83%) (Table 16). Even for cars with at least 2 occupants and at least one fatality, in 70% of cases only one of the car occupants was killed.

In 83% of the 277 fatal, frontal impacts with another vehicle, the only person(s) killed were in the car and no one in the other vehicle was killed.

Nineteen fatal, frontal impacts (4%) resulted in a fire or explosion. In 11 of these, at least one fatality was attributed to the fire.

Table 16. Crash outcome for occupants of 441 of cars sustaining frontal impacts resulting in at least one occupant fatality (FORS 1990 Fatality File)

Crash outcome	n	%
Total cars	441	100%
Number of car occupants killed		
1	366	**83%**
2	65	15%
More than 2	10	2%
Whether additional persons in other vehicles also killed		
Single vehicle crash (no other vehicles involved)	164	-
Multiple vehicle crash, no other persons killed	229	**83%**
Multiple vehicle, at least one other person in other vehicle killed	48	17%
Whether crash results in a fire or explosion		
No	422	**96%**
Yes (at least one occupant died in the fire)	11	2%
Yes (no occupants died as a result of the fire)	8	2%

Fatalities and seat belt use

Of the 528 car occupants killed in frontal impacts, 318 (60%) were recorded as wearing a seat belt (or in a restraint) at the time of the crash, 112 (21%) were unrestrained and for 98 (19%) this information was not recorded. Excluding the missing values, the resultant percentage not wearing seat belts is 26%.

Injury outcome in different seating positions

Table 17 summarises the occupancy rate in each of the 6 primary seating locations in passenger cars sustaining fatal frontal impacts (3 in the front and 3 in the back). It also tabulates the severity of injury for the occupants in each seating position.

In three quarters of the fatal frontal impacts the driver was killed. In a further 18% of cases, the driver was hospitalised and in the remaining 8% the driver escaped serious injury (Table 17).

Only four of the cars had a passenger sitting in the centre front seat. Of these, 3 were killed and one sustained injury requiring hospitalisation.

Half of the cars had a passenger sitting in the front left seat. Of these 219 persons, 123 (56%) were killed and 73 (33%) required hospitalisation.

The overall percentage of drivers killed is not directly comparable with the percentage of occupants killed in the other seating positions (Table 17). This is because all the cars have a driver and, by definition, there is at least one fatality in each car. A more appropriate comparison is between the percentage of drivers killed in cars which have at least one passenger. This figure is 55%. This is similar to the percentage of front left passengers killed (56%) and, as expected, higher than the percentage of rear seat passengers killed (33-42%) (Table 17).

Of the cars with passengers, the percentage of drivers hospitalised (31%) is also similar to the percentage of front left passengers hospitalised (33%).

Table 17. The number and percentage of cars with various seats occupied, and the number and percentage of cars with fatalities and hospitalisations in each seating position (given that position was occupied) for 441 cars sustaining frontal impacts resulting at least one fatality (FORS 1990 Fatality File)

	Seat occupied		Fatally injured		Hospitalised		Minor/not injured	
Seating position	n	%	n	%	n	%	n	%
Driver	439	100%	325	74%	77	18%	37	8%
Front centre	4	1%	3	75%	1	25%	0	0%
Front left	219	50%	123	56%	73	33%	23	11%
Rear right	41	9%	14	34%	23	56%	4	10%
Rear centre	26	6%	11	42%	12	46%	3	12%
Rear left	57	13%	19	33%	29	51%	9	16%

Occupants ejected or trapped

Overall, 39% of drivers and 27% of passengers were trapped as a result of fatal frontal impacts (Table 18). All these persons were not necessarily killed. Their injury status is discussed in a later section.

Overall, only about 5% of front seat occupants were ejected from their vehicles as a result of the impact. Most of these were not wearing seat belts. A seat belt failure was noted in one of the cases of ejection despite wearing a seat belt.

The most appropriate comparison between drivers and passengers is restricted to those impacts to cars with both a driver and passenger (the last two columns of Table 18). The percentages of drivers and passengers trapped or ejected are not statistically significantly different.

Table 18. *Percentage distribution of drivers (D) and front left passengers (FL) trapped in or ejected from cars sustaining frontal impacts resulting in at least one occupant fatality (FORS 1990 Fatality File). These occupants are not necessarily killed. Drivers are also shown separately according to the presence of a front left passenger and ejection status is shown separately according to whether a seat belt was known to be worn or not. For approximately 15% of occupants seat belt status was unknown. These are not shown separately.*

Crash outcome in terms of being trapped or ejected	Drivers							
	All drivers		Drivers with no FL passengers		Drivers with FL passenger		FL passengers with driver	
	D	%	D	%	D	%	FL	%
Trapped								
No	249	61%	113	55%	136	66%	151	73%
Yes	161	39%	91	45%	70	34%	55	27%
Total known	410	(100%)	204	(100%)	206	(100%)	206	(100%)
Ejected								
No	412	96%	209	96%	203	95%	203	95%
Yes	19	4%	8	4%	11	5%	11	5%
Total known	431	(100%)	217	(100%)	214	(100%)	214	(100%)
Seat belt worn								
Not ejected	283	99%	131	100%	152	99%	147	99%
Ejected	2	1%	0	0%	2	1%	1	1%
Total known	285	(100%)	131	(100%)	154	(100%)	148	(100%)
Seat belt not worn								
Not ejected	59	85%	38	91%	21	78%	27	79%
Ejected	10	15%	4	9%	6	22%	7	21%
Total known	69	(100%)	42	(100%)	27	(100%)	34	(100%)

Driver and passenger fatalities

Just over two thirds of the drivers killed in fatal, frontal impacts were male. In vehicles with a front left passenger, 73% of the drivers killed were male compared with only 42% of the passengers killed (Table 19). The age distribution of passenger fatalities is more varied than driver fatalities.

Approximately one in five drivers and passengers killed in fatal, frontal impacts were not wearing seat belts at the time of the crash, but for almost as many, this information was not stated. For the cars with both a driver and a passenger, more of the passengers killed were not wearing belts (21%) compared with the drivers killed (12%). These figures are considered underestimates of the seat belt non-wearing rate as some of those for which this information was not stated may not have been restrained.

Being trapped in the car is common for both driver and front passenger fatalities in frontal impacts, but the ejection rate is only between 5% and 7%. Of the 16 driver fatalities ejected from their vehicles, 8 were not wearing seat belts; belt status was unknown for 6; there was a strap failure for one and the belt status was recorded as worn for the other. The breakdown for the 8 passenger fatalities was 4 unbelted, 3 unknown and one belted with no failure recorded.

Approximately one quarter of the drivers killed in fatal, frontal impacts were drunk. Drivers carrying passengers were less likely to be drunk (13%) than drivers with no passengers in the front seat (29%). The corresponding percentage with BAC over 0.05 is 13% for passengers. However, fewer of the passengers were tested for alcohol.

Table 19. Characteristics of 325 driver (D) and 123 front, left passenger (FL) fatalities in cars sustaining frontal impacts (FORS 1990 Fatality File). (Drivers are also divided according to the presence of a front left passenger in their vehicle)

	Driver fatalities						FL passenger	
	All driver deaths (n=325)		FL not occupied (n=204)		FL occupied (n=121)		fatalities (n=123)	
Characteristics	D	%	D	%	D	%	FL	%
Sex								
Male	220	**68%**	132	**65%**	88	**73%**	51	**42%**
Female	105	32%	72	35%	33	27%	72	58%
Age group								
<5	0	0%	0	0%	0	0%	1	1%
5-16	1	0%	0	0%	1	1%	7	6%
17-24	107	**33%**	60	29%	47	**39%**	39	32%
25-39	90	28%	61	**30%**	29	24%	22	18%
40-59	61	19%	45	22%	16	13%	13	10%
60+	66	20%	38	19%	28	23%	41	**33%**
Seat belt/restraint								
Worn	213	**66%**	126	**62%**	87	**72%**	75	**61%**
Not stated	56	17%	37	18%	19	16%	22	18%
Not worn	56	17%	41	20%	15	12%	26	21%
Trapped								
No	157	**52%**	98	**52%**	59	**52%**	70	**61%**
Yes	145	48%	90	48%	55	48%	45	39%
Ejected								
No	304	**95%**	193	**96%**	111	**93%**	112	**93%**
Yes	16	5%	8	4%	8	7%	8	7%
BAC								
Not tested	59	20%	34	17%	25	21%	46	**43%**
<=0.05 gm/100 ml	163	**55%**	94	**46%**	69	**57%**	46	**43%**
> 0.05 gm/100 ml	76	25%	60	29%	16	13%	14	13%

Injury severity and pattern for front seat fatalities

A majority of fatalities occurred before medical assistance (Table 20). Often, it is not possible to distinguish instantaneous deaths from those which occurred before help arrives.

For approximately 80% of the fatally injured car occupants, there is detailed coding in the FORS 1990 Fatality File concerning the severity and location of the injuries according to the 1990 Revision of the Abbreviated Injury Scale (AIS). Injuries to the head, face, neck, thorax, abdomen/pelvic contents, spine, upper extremities, lower extremities and other unspecified/external regions are graded from 1 to 6 with respect to severity. Grade 3 corresponds to serious, 4 severe, 5 critical and 6 is the maximum. A maximum of 12 injuries with severity at least grade 2 are coded for any one fatality in the 1990 Fatality File. This level of detail is not available for those persons injured, but not killed.

The injury severity and location for the 275 drivers and 100 front, left passengers killed in frontal impacts for whom the AIS coding is available are summarised in Table 20 in terms of the following measures:

- the total number of severe or worse injuries (AIS 4-6). It should be noted that a person may sustain more than one severe injury to a single body region.

- the Injury Severity Score (ISS). This is the sum of the squares of the maximum AIS severity score for the three most severely injured regions. Scores above 75 are coded as 75, ie. corresponding to at least 3 regions with severity score at least 5. A score of 75 is also assigned for individuals with a severity score of 6 in any single region. The scores have been grouped into four categories in Table 20.

- the presence of at least one severe or worse injury to each of the specific body regions (eg at least one severe or worse injury to the head)

- various combinations of severe or worse injuries in different body regions (eg head only, chest only, head and chest only).

Injury severity

Although the majority of persons killed in frontal impacts sustained at least one injury coded as severe or worse, there were between 13% and 17% who died of injuries coded 3 (serious) or less. Almost one in five sustained more than three severe injuries. The number of severe injuries and the distribution of ISS is similar for both driver and passenger fatalities.

Table 20. Injury severity and pattern for driver (D) and front left passenger (FL) fatalities in cars sustaining frontal impacts (FORS 1990 Fatality File). (Drivers are also divided according to the presence of a front left passenger in their vehicle)

	Driver fatalities						FL passenger fatalities	
	All driver deaths		FL not occupied		FL occupied			
Fatality details	D	%	D	%	D	%	FL	%
Timing of death		(319)[1]		(199)		(120)		(122)
Instantaneous	67	21%	37	19%	30	25%	30	25%
Before med. attention	154	**48%**	95	**48%**	59	**49%**	37	30%
During med. attention	14	4%	6	3%	8	7%	6	5%
In transit	10	3%	9	4%	1	1%	6	5%
In hospital	74	23%	52	26%	22	18%	43	**35%**
Number[2] of severe or worse injuries (AIS 4-6)[3]		(275)		(175)		(100)		(100)
None	39	14%	22	13%	17	17%	17	17%
1	65	**24%**	39	**22%**	26	**26%**	29	**29%**
2	63	23%	42	24%	21	21%	27	27%
3	56	20%	40	23%	16	16%	10	10%
4+	52	19%	32	18%	20	20%	17	17%
Injury severity score (ISS)		(275)		(175)		(100)		(100)
<25	53	19%	30	17%	23	23%	27	27%
25-39	103	**37%**	66	**38%**	37	**37%**	34	**34%**
40-74	68	25%	44	25%	24	24%	19	19%
75	51	19%	35	20%	16	16%	20	20%
At least one severe injury (AIS 4-6)		(275)		(175)		(100)		(100)
Chest	167	**61%**	109	**63%**	58	**58%**	52	**52%**
Head	150	**54%**	98	**56%**	52	**52%**	43	**43%**
Abdomen/pelvic contents	37	14%	26	15%	11	11%	18	18%
Spine	6	2%	3	2%	3	3%	7	7%
External	4	1%	3	2%	1	1%	2	2%
Neck	4	1%	2	1%	2	2%	0	0%
Lower extremity	4	1%	4	2%	0	0%	0	0%
Upper extremity	0	0%	0	0%	0	0%	0	0%
Combinations of severe injuries (AIS 4-6)		(275)		(175)		(100)		(100)
Head and chest only	69	**25%**	42	24%	27	**27%**	11	11%
Chest only	64	23%	43	**25%**	21	21%	27	**27%**
Head only	55	20%	36	21%	19	19%	20	20%
All injuries less than AIS 4	39	14%	22	13%	17	17%	17	17%
Other region or other combination of severe injuries	22	8%	12	7%	10	10%	13	13%
Head, chest, abdomen/pelvis	13	5%	11	6%	2	2%	7	7%
Head and other region	13	5%	9	5%	4	4%	5	5%

[1] The percentage baseline counts differ according to different numbers of missing values.
[2] The total number of injuries may involve multiple severe injuries to the same body region.
[3] AIS 4-6 corresponds to injuries coded severe, critical or maximum on the Abbreviated Injury Scale.

Injury location and pattern

The head and chest are the two regions most likely to sustain severe injuries for front seat occupants killed in frontal impacts. The incidence of severe chest injuries was slightly higher than head injuries for both drivers and passengers. Injuries to the abdomen and pelvis region were the third most common, but markedly less than for the head and chest. The incidence of severe spinal injuries was relatively low, but somewhat higher for passenger deaths (7 cases, 7%) than for driver deaths (6 cases, 2%).

Occupants killed tended to have suffered injuries to more than one body region. For example, while 61% of drivers killed had at least one severe injury to the chest, only 23% of drivers killed had all severe injuries confined to the chest region. Similarly, while 54% of all drivers killed sustained at least one severe head injury, only 20% of drivers killed had all severe injuries confined to the head.

The most common combination of severe injuries for driver fatalities was head and chest only (27%). The most frequent 'combination' for the passenger fatalities was chest only (27%).

Further analysis of the number and location of fatal injuries taking into account other factors such as age, sex, seat belt status, and seating position is reported in the next chapter.

Height and weight of occupant fatalities

Height and weight were recorded in the FORS 1990 Fatality File for approximately half of the drivers and passengers killed. The missing data were equally likely for males and females, drivers and passengers, and for those wearing a seat belt or not. However, there was a relationship with age, State and urban/rural status. Height and weight were least likely to be recorded for older persons, persons from NSW and those from rural areas.

For those individuals with data, the height and weight of drivers and adult front left passengers killed in frontal impacts were compared. Males were on average, approximately 10 cm taller and 10 kg heavier than females. However, male drivers and passengers were of similar height and weight. The mean heights and weights of female drivers and passengers were also similar. Even when allowing for differences in age, State and urban/rural status, there was no statistically significant difference (within the sexes) between the heights or weights of the driver and adult front seat passenger fatalities.

4. Subgroup comparisons: full frontal versus frontal offset impacts

4.1 Introduction

The 309 full frontal impacts, the 85 offset right frontal impacts and the 47 offset left frontal impacts are now compared in terms of the pre-crash setting, the crash event and the crash outcome. Full frontal impacts are almost always at right angles and tend to involve damage to the whole of the front of the car. By definition, offset left frontal impacts involve damage to the passenger's side of the front of the car and offset right frontal impacts involve damage to the driver's side of the front of the car (Figure 4). Offset impacts may be either at right angles or at any angle to the front of the car (Figure 5).

The degree of comparison between these three groups in terms of the factors mentioned in the previous chapter is limited by the relatively small number of offset impacts and the need to adjust for occupancy in some cases, especially in comparisons between the driver's side and passenger's side offset impacts.

The terms *near side* and *far side* offset will be used to refer the site of the impact relative to the seating position. For example, a front right or driver's side frontal offset impact is near side for drivers and far side relative to front seat passengers.

4.2 Pre-crash setting

The pre-crash setting was generally similar for the full frontal and offset impacts, except that offset frontal crashes were more likely to occur within intersections than full frontal crashes. Though only about one in five offset frontal impacts occurred within intersections (passenger's side 23% and driver's side 19% at intersections), this is twice as likely than for full frontal impacts (only 11% at intersections) (Table 21).

4.3 Crash event

Crash characteristics

Driver's side offset crashes were more likely to be multiple vehicle crashes than full frontal or passenger's side offset crashes (74% vs 60%) (Table 21).

Within the group of 277 **multiple vehicle crashes**, there were no statistically significant differences between the 186 full frontal, 63 driver's side and 28 passenger's side offset impacts in terms of the type of crash. However, there was a slightly lower percentage of head to head crashes for the passenger's side offset crashes compared with the other types (Table 21). This is consistent with expectation, since the passenger's side is furthest from opposing traffic.

Of the 164 **single vehicle crashes** involving cars sustaining fatal frontal impacts, the full frontal impacts and the driver's side offset impacts were more likely to occur off the carriageway than the passenger's side offset impacts (Table 21). These were more likely to involve collisions with parked cars or poles and the full frontal and driver's side offset impacts were more likely to involve running into a tree.

So, for both multiple vehicle and single vehicle crashes the characteristics of driver's side offset crashes were more like full frontal offset crashes than passenger's side offset crashes.

Car details

The percentage of smaller, lighter cars was highest for full frontal (35%) and driver's side offset impacts (39%) and lowest for passenger's side offset impacts (17%, Table 21). This was also the case even when the analysis was restricted to those cars with at least one passenger (33% and 33% vs 16% for full frontal, driver's side and passenger's side offset).

At least half of the cars in all the groups were estimated to be travelling at least 100 kph. Even though there were very few cars estimated to be travelling at less than 60 kph, cars with offset impacts were more likely to be travelling slowly than cars with full frontal impacts (9% vs 2%). Most of these vehicles were turning or manoeuvring (Table 21).

Causal factors

Full frontal impact crashes were less likely to be explained by typical causal factors such as alcohol intoxication, speeding, other driver error, fatigue or critical vehicle malfunction than the frontal offset crashes (39% of full frontal impact crashes unexplained vs 25% of frontal offset impact crashes unexplained).

Passenger's side offset crashes were more likely to be caused by car driver error (17%) than full frontal impact or driver's side offset impact crashes (5% and 8%, respectively). The errors noted most commonly included inattention or failure to observe another vehicle or traffic signal. Driver error is often not recorded in cases where the driver is killed, since a witness statement is required, so the higher percentage of passenger's side offset crashes attributed to driver error may just reflect that more drivers survived these crashes.

Passenger's side offset crashes were also more likely to be caused by a car defect (9%) than full frontal impact and driver's side offset impact crashes (1%). The number of vehicles with defects is too small, however, to identify particular patterns.

Drivers and passengers

The age and sex distribution of drivers involved in full frontal and offset impacts was similar. There was a tendency, however, for a higher proportion of drivers in passenger side impacts to be unbelted (26% vs 13% unbelted in driver's side offset and 15% unbelted in full frontal). So, drivers in far side offset impacts were less likely to be wearing a seat belt than drivers in near side offset impacts. This is discussed further in the next section on crash outcome.

Cars involved in passenger side offset crashes were more likely to contain passengers (81%) than cars involved in offset right impacts or full frontal impacts (both 54% with passengers). This is consistent with expectation, since most passengers sit in the front left seat.

There was a slightly higher percentage of female passengers sitting in the front of cars involved in full frontal impacts (61%) compared with offset impacts (passenger side offset 43% female passengers; driver's side offset 47% female).

Front seat passengers in cars sustaining offset passenger's side impacts were less likely to be wearing seat belts (32% unbelted) than passengers subject to full frontal impacts (12% unbelted) and driver's side impacts (13% unbelted). So, passengers in near side impacts were less likely to be wearing seat belts than passengers in full frontal or far side impacts. This is different to that reported for drivers in the previous section, which were least likely to be wearing seat belts in *far side* impacts.

Table 21. Pre-crash and crash event characteristics for 309 cars sustaining fatal full frontal impacts compared with 85 cars sustaining fatal frontal right side offset impacts and 47 cars sustaining left offset impacts (FORS 1990 Fatality File). Shaded regions indicate percentages calculated on subsets of the data.

	Offset left (passenger's side)		Full frontal (central)		Offset right (driver's side)	
Crash characteristics	n	%	n	%	n	%
Whether at intersection						
Mid block	36	77%	275	**89%**	69	81%
Intersection	11	**23%**	34	11%	16	**19%**
Number of moving vehicles in crash						
Multiple vehicle	28	60%	186	60%	63	**74%**
Single vehicle	19	**40%**	123	**40%**	22	26%
Multiple vehicle crashes (277 cars)						
Vehicles from opposite directions	20	71%	154	83%	55	87%
Vehicles from adjacent directions	4	14%	13	7%	6	10%
Other	4	14%	19	10%	2	3%
Single vehicle crashes (164 cars)						
Off carriageway	14	74%	112	**91%**	21	**95%**
On carriageway	5	**26%**	11	9%	1	5%
Mass of car sustaining frontal impact						
Light (<1100 kg)	8	17%	108	**35%**	33	**39%**
Medium (1100-1300 kg)	20	43%	122	39%	25	29%
Heavy (>1300 kg)	19	**40%**	79	26%	27	32%
Estimated speed of car sustaining frontal impact						
<60 kph	5	**11%**	5	2%	7	**8%**
60 kph	6	13%	41	13%	9	11%
65-95 kph	14	30%	74	24%	20	24%
>=100 kph	22	47%	189	61%	48	57%

4.4 Crash outcome

Occupants trapped or ejected

Consistent with expectation, drivers were more likely to be trapped in offset impacts on their side of the car than in a passenger's side offset impact. For example, 45% of drivers were trapped in near side offset impacts compared with only 10% trapped in far side offset impacts. Similar figures were obtained after restricting the calculations to those drivers killed. The passenger figures show a similar pattern with 50% of passengers trapped in near side impacts and only 15% trapped in far side impacts. Again, the pattern was similar among passenger fatalities.

Overall, 42% of drivers and 25% of passengers were trapped in full frontal impacts. The most appropriate comparison of the likelihood of being trapped in full frontal impacts according to seating position is to restrict attention to those cars where there is both a passenger and a driver in the front. There are 137 such cases with information on both occupants. In most cases, neither (72) or both (25) are trapped. However, in the other cases where only one is trapped, the driver is significantly more likely to be trapped than the passenger (30 cases with the driver trapped but not the passenger compared with only 10 cases where the passenger is trapped and not the driver).

The small number of drivers (19) and passengers (11) ejected from cars involved in frontal impacts precludes disaggregation by impact type.

Fatalities

The overall proportions of male and female car occupants killed were similar for all three types of frontal impacts (approximately 60% male, 40% female).

There were 242 drivers killed in full frontal impacts (78%), 71 drivers killed in near side offset impacts (85%) and 12 drivers killed in far side offset impacts (26%).

The number of drivers and passengers killed are compared for those cars for which the two front seat positions are occupied (219 cars). Overall, 55% of drivers and 56% of passengers died.

The proportions of drivers killed and passengers killed are similar for full frontal impacts (62% and 55%). Table 22 shows the different combinations of fatalities by the three different types of frontal impacts. In 101 of the 145 cars sustaining full frontal impacts only one of the two front seat occupants died. In 56 cases the driver died and the passenger survived, and in 45 cases the passenger died and the driver survived. These two numbers are not statistically significantly different.

In the offset impacts, as expected, one is more likely to die in a near side impact than a far side impact. Overall, 97% of passengers died in near side impacts (33 out of 34) and 28% died in far side offset impacts (11 out of 40). Also, 70% of drivers died in near side impacts (28/40) and only 9% died in far side offset impacts (3/34, Table 22).

Though the number of offset impacts is small, these figures seem to suggest a greater risk to passengers than drivers in both near and far side offset impacts. In fact, there were seven cases in which the driver survived a near side impact but the passenger died and no cases where the reverse occurred (Table 22). It is expected that this could at least partially be explained by other factors, such as gender and seat belt use of occupants. We have already seen that passengers were slightly less likely than drivers to be wearing seat belts. Also, a higher percentage of front left passengers were female, and females have been shown to have a greater risk of death compared with males when subject to the same impact. The small number of cases precludes further analysis of these data. However, Evans and Frick, after adjustment for such factors, found no differential risk between passengers and drivers for all types of frontal impacts in earlier FARS data[1].

Table 22. Number and percentage of cars with different combinations of fatalities among drivers and front left passengers within the three frontal impact types (offset left, full frontal, offset right) (FORS 1990 Fatality File). All cars have a driver and a passenger in the front left seat.

Fatality combinations of front seat occupants	Offset left (passenger's side) n	%	Full frontal (central) n	%	Offset right (driver's side) n	%
Both driver and passenger die	3	9%	34	23%	4	10%
Driver dies, passenger survives	0	0%	56	39%	24	60%
Driver survives, passenger dies	30	88%	45	31%	7	18%
Both survive (other occupant dies)	1	3%	10	7%	5	12%
Total cars	34	100%	145	100%	40	100%

Fatalities and seat belt use

As previously noted for *all* drivers involved, drivers *killed* in far side offset impacts were less likely to be wearing a seat belt (50% unbelted, 6 out of 12) than drivers killed in either full frontal impacts (21% unbelted, 41 out of 193) or near side impacts right impacts (14% unbelted, 9 out of 64). This is consistent with expectation, since a near side impact is more likely to be fatal regardless of seat belt use.

The same pattern was not observed for passengers, with the highest non-wearing rates among the *near side* fatalities (38%, 10 out of 16). However, this percentage was not statistically significantly different from that for the other frontal impact types (full frontal 22% unbelted, 14 out of 65; far side offset 20% 2 out of 10). It should be noted that these calculations exclude 18% of the passenger fatalities on the grounds of missing data on seat belt use.

Summarising the data on seat belt use for fatalities in all seating positions shows a markedly higher percentage of occupants killed in passenger side offset crashes to be unrestrained (49%, excluding missing) compared with 26% for full frontal impacts and 20% for driver's side offset impacts.

Injury severity and injury location

Detailed information on the severity and location of injuries was available for 203 drivers killed in full frontal impacts, 61 drivers killed in near side offset impacts and 11 far side offset impacts. The severity and location of injuries to drivers fatally injured in full frontal impacts were not statistically significantly different to those of drivers fatally injured in frontal right or left offset crashes.

In spite of the small numbers, a comparison of drivers and passengers killed in near side offset impacts showed that passengers killed in near side impacts were more likely to sustain severe spinal injuries (15%, 4 cases out of 26) than drivers killed in near side impacts (3%, 2 cases out of 61).

Multiple logistic regression analyses were performed in order to determine the predictors of the various injury severity and injury location measures for driver fatalities and passenger fatalities which occurred as a result of frontal impacts. The following outcome measures were analysed separately:

- the number of severe injuries to any body region (none or one vs more than one)
- presence of severe head injuries (none vs at least one)
- presence of severe chest injuries (none vs at least one).

Sex, age, seat belt use, BAC level, size of car, estimated speed of car, number of vehicles in the crash and type of impact were considered as potential explanatory variables. Separate analyses were performed for driver and front left passenger fatalities for each of the three injury outcome measures. There were 176 driver deaths and only 46 front left passenger deaths with complete information on both the explanatory and the outcome variables. Multivariate modelling of the passenger data was restricted by the small number of cases.

Age was statistically significantly associated with the number of severe injuries among the drivers killed, and specifically, the incidence of severe head injuries among both drivers and passengers. The likelihood of more than one severe injury *decreased* with age and the result held even with adjustment for other factors. Only 43% of drivers killed who were 60 or older had more than one injury coded as severe, compared with 68% of drivers under 60. The results for head injuries were similar, with a higher percentage of younger drivers and passenger fatalities sustaining head injuries compared with the older driver and passenger fatalities. Presumably this just reflects that older persons die of less severe injuries and injuries to other body regions. This is consistent with a recent report by Wood[2].

None of the factors tested was statistically significantly related to the number of severe chest injuries among either the driver or passenger fatalities.

5. Summary

The major findings are discussed in this final chapter. The distinguishing features of frontal impacts are summarised as well the major differences between central and offset impacts, and specifically driver's side versus passenger's side offset frontal impacts.

5.1 Frontal impacts

The crashes studied in this report represent an important group in accident analysis due to their frequency and severity. Car occupants comprise half the persons killed on roads in any one year and frontal impacts account for just under half (46%) of crashes resulting in car occupant fatalities. In 1990 in Australia, 528 persons were killed in 441 cars as a result of impacts to the front of the vehicle they were travelling in. In approximately 70% of these collisions, the impact was a perpendicular force centrally located on the front of the car. The remaining frontal impacts were off centre.

5.2 Frontal crash characteristics

Crash event

A possibly common misconception is that frontal crashes are primarily head on crashes between vehicles. Certainly this is the case for multiple vehicle crashes with 82% head to head. However, over one third (37%) of all frontal impacts involve a car running into a fixed object

Approximately 75% of **multiple vehicle crashes** involved a car running into a vehicle of larger mass. This 75% is made up of other cars of a larger weight class (21%), other larger passenger vehicles such as vans, 4 wheel drive vehicles, utilities and light trucks (23%), and finally buses and trucks (31%). It is thus not surprising that in 83% of cases where car occupants are killed in a collision with another vehicle, there were no fatalities in the other vehicle.

The most common multiple vehicle collision involved two vehicles travelling from opposite directions (228 impacts). Only a small number of these (16) involved overtaking or one vehicle turning at an intersection (10). Collisions with the rear of another vehicle accounted for a further 18 multiple vehicle frontal impacts.

The **single vehicle collisions** typically involved the car losing control and running off the road into objects such a trees (89%). Other single vehicle frontal impacts involved collisions with objects on the carriageway, such as parked cars, signs or poles. The number of single vehicle crashes on straight and curved roads was similar.

Crash site

Just over half of the frontal impacts occurred on roads in rural areas. This was the case for both single and multiple vehicle collisions. Interestingly enough, a considerable proportion, (just under half) of these rural crashes occurred on roads other than National or State Highways. In fact, 87% of impacts in non-intersection crashes occurred on two way undivided roads.

Taking into account the speed limit and the available information on whether the car drivers were speeding or within intersections resulted in the estimation that 59% of the cars were probably travelling at speeds of at least 100 kph before the crash. Only about 17% were estimated to be travelling at or below 60.

The timing of crashes and driving conditions were consistent with fatal crashes in general, with 60% percent of the frontal impacts occurring on week days and 55% of the crashes occurring during the daylight hours.

Causal factors

In 152 of the 441 fatal frontal impacts (34%) no explanation could be found for the road user action which lead to the crash. Alcohol intoxication was implicated in 120 (27%) of the 441 frontal impacts. Twenty-four percent of the car drivers were over the legal limit of 0.05. (A further 22% were not tested). The percentage of alcohol related impacts was as high as 40% for the single vehicle crashes. Excessive speed was noted as a contributing factor in 17% of the frontal impacts. The incidence of this factor was also markedly higher for the drivers involved in single vehicle crashes (27%). In 13% of crashes, fatigue was noted as a possible contributing factor and in 11% of the crashes it was noted that the car lost control on the left shoulder of the road.

Persons involved

Seventy-two percent of the car drivers involved were male and 35% we aged under 25. Twenty percent of the drivers were aged 60 or more. The mean age was 38 years. The male drivers involved tended to be tradesmen, labourers or retirees, whereas the majority of the females either worked in the sales/service sector or were at home. Overall, 6% were unemployed.

Seventy car drivers were not wearing seat belts at the time of the crash. This represents 16% of the total or 19% of those drivers for which this information was recorded in the 1990 Fatality File.

The driver was the sole occupant in 43% of the cars. Male drivers were more likely to be carrying passengers than female drivers, but drivers carrying passengers were, on average, the same age as drivers travelling alone. The second most common seating combination after 'driver only' was driver and front left passenger (28%). The mean age of drivers and front left passengers was similar (38 years) and 64% of passengers were within 5 years of the driver's age. Only 7% of front left passengers were children under 17 years of age. The most common driver/front left passenger combination was a male driver and a female passenger (95 cases, 43%). The next most common combination was a male driver and male passenger (74 cases, 34%).

5.3 Injury outcome

Severity

Three quarters of the car drivers involved in frontal impacts were killed. In the cars with two front seat occupants, approximately half of the drivers and half of the front left passengers were killed. Of the cars that contained passengers in the back, these passengers had a lower death rate than the front seat occupants. Thus, consistent with expectation, the likelihood of being killed increased with the proximity of the impact.

This was also the case in comparing the offset impacts, ie. drivers were more likely to be killed in impacts offset on their side of the vehicle. The proportions of drivers killed in near side, full frontal and far side (passenger side) offset impacts were 85%, 78% and 26%, respectively. Restricting the percentage calculations to cars with front left occupants, the percentages of drivers killed are 70%, 62% and 9%, also decreasing as the impact is further from the driver. The percentages of front left passengers killed are also consistent with expectation; 97% of passengers killed in near side impacts, 55% killed in full frontal impacts and only 28% killed in far side impacts.

These figures show some evidence that passengers may be more vulnerable than drivers to both near side and far side offset impacts, but not full frontal impacts. However, the small number of crashes precludes a detailed analysis taking into account important factors such as gender, age and seat belt use.

Occupants trapped or ejected

It was also shown that drivers had a greater chance of being trapped in full frontal crashes than passengers sitting next to them. This could probably be attributed to the steering wheel.

The number of front seat passengers who were ejected was low (5% overall) and detailed analysis of these cases was not warranted.

Injury location and pattern

Detailed information on the location and severity of injury was only available for those persons killed in the crash, no such details were available for persons injured but not killed. The most common body regions sustaining severe injury were the head and chest. The occupants killed tended to have suffered multiple injuries often to different body regions.

The number and location of injuries recorded for the persons killed did not appear to be consistently related to gender, seat belt status, seating position, BAC level, car size or impact type. There was, however, a higher percentage of severe head injuries among the younger driver and front passenger fatalities compared to those aged 60 or more and this was consistent with an earlier reported finding.

5.4 Full frontal versus frontal offset crashes

The 441 fatal frontal impacts are not a uniform group. The majority of them are central and at right angles to the frontal bumper bar. However, at least 30% are off centre, with more offset on the driver's side than on the passenger's side. The main reason for the imbalance is the different occupancy rates. The front left passenger seat was occupied in only half of the cars.

Whereas almost all the full frontal impacts were perpendicular, only approximately half of the offset impacts were at right angles to the front. There was also some indication that a slightly higher percentage of the driver's side offset impacts were perpendicular compared with the passenger's side offset impacts.

The major difference with respect to the crash setting was that offset frontal impacts were more likely to occur within intersections than full frontal impacts (20% vs 11%). This was also reflected in that there were higher percentages of offset frontal impacts occurring a speeds estimated to be less than 60 kph.

5.5 Driver's side versus passenger's side offset impacts

Although comparisons within the group of offset crashes were restricted by the small number of crashes (especially since in most cases the occupancy had to be taken into account), some major differences between the driver's side and passenger's side offset frontal impacts emerged.

Passenger's side offset impacts were more likely to be single vehicle crashes (40% vs 26%) and these single vehicle crashes differed as well. The passenger side offset impacts were more likely to involve hitting a parked car or object on the carriageway, whereas the driver's side single vehicle crashes typically involved running off the road into a tree.

There were no statistically significant differences within the group of multiple vehicle crashes, but it is interesting to note that in terms of the different crash types, the driver's side offset impacts were similar to the full frontal impacts (ie. a higher percentage of head on crashes).

Another difference between the offset impacts was the car size. Even after adjusting for occupancy, driver's side offset impacts involved a higher percentage of smaller, lighter cars than passenger side offset impacts. This was another feature in which the driver's side offset impacts were similar to the full frontal impacts.

The percentage of car occupants killed in passenger side offset frontal crashes who were not wearing seat belts was higher than the corresponding percentage in the other types of frontal crashes.

5.6 International comparison

The overall percentage of frontal impacts causing car occupant fatalities was similar for fatal crashes in Australia in 1990 and fatal crashes in the US in 1991 and 1992. There were slightly more full frontal impacts relative to offset impacts in the US data compared with Australia, but this may just be related to the slightly different coding systems.

Australian and US frontal crashes were also similar in terms of many of the crash site factors which could be compared. However, the proportions of frontal crashes which occurred on rural highways, on straight sections and on divided roads were higher in the US than observed in Australia. These differences may just reflect the overall differences in road configuration in the two countries.

References

1. Seating position in cars and fatality risk. Evans L and Frick M. *Am J Public Health* Vol 78 1456-1458 1988
2. Analysis of medical data from fatal road crashes. Wood JT, O'Neill T, Donnelly C. FORS CR 129 1994

Appendix

Fatality File coding: point and direction of impact

This section contains the definition of the different impact types in terms of the Australian 1990 Fatality File items. Point of primary impact (PIMP) and direction of impact (DIMP) are the two vehicle items on which the definition is based.

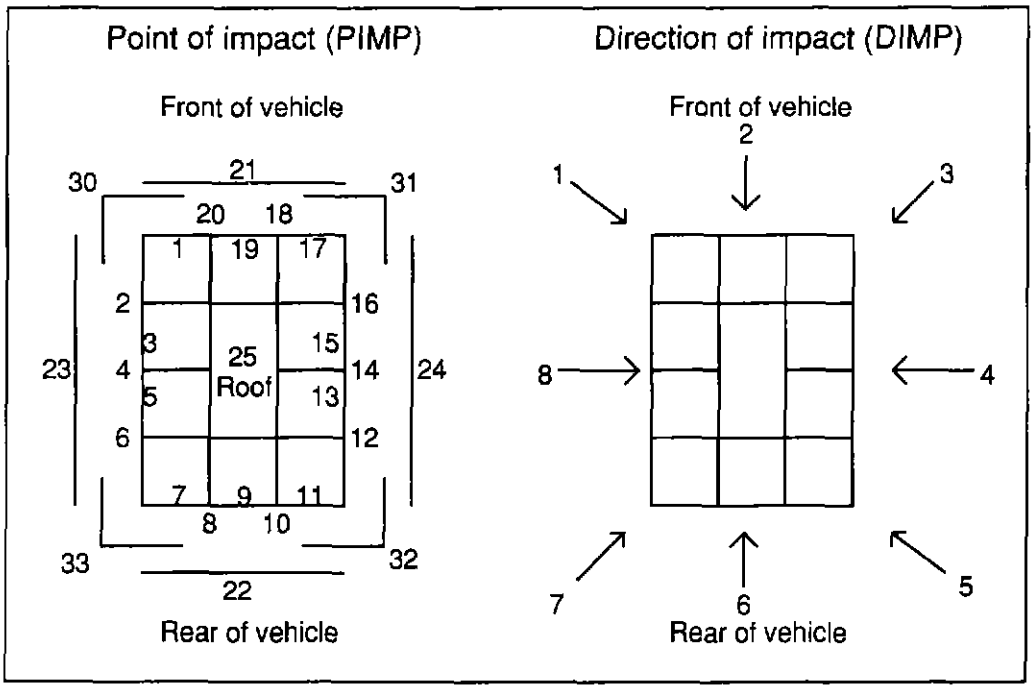
The *point* of primary impact (PIMP) is defined as the impact point on the vehicle which most likely caused the fatality. In the Fatality File coding scheme the surface of the vehicle is divided into 11 specific areas and other codes are allocated if the impact involved more than one of these specific areas or the fatality was a result of the vehicle overturning (Figure A1).

For example, if the impact was spread over the whole of the front of the vehicle (eg codes 1,19 and 17 on Figure A1) the point of impact is coded 21, whereas if the damage was confined to only the centre front (code 19) and the front left (code 1), then the point of impact is coded 20. The L-shaped corner codes (30, 31, 32, 33) are used in cases where there is a diagonal impact to the corner or where there is damage to both sides but the actual point of impact is unclear.

Separate codes (not shown on the figure) are used for undercarriage (26) and overturn (27). Code 28 is used for cases where the vehicle occupant death is not due to an impact or overturn, for example, immersion in water, electrocution, an earthquake or falling from the vehicle where there is no impact. These cases are excluded.

The *direction* of impact (DIMP) is the direction of the primary impact (Figure A1). The direction of impact is not applicable for overturn impacts.

Figure A1. Coding schemes for the point of primary impact (PIMP) and direction of primary impact (DIMP), items B22 and B23, for vehicles in the 1990 Fatality File



Major impact types

Frontal, right side and left side impacts and the component subdivisions of these are defined as various combinations of the PIMP Fatality File codes. This is illustrated diagrammatically (Figure A2) and tabulated in Table A1. The direction of impact (DIMP) is only used to divide the L-shaped corner impacts into front or side impacts.

Full frontal impacts (FF) comprise mainly those impacts to the whole of the front of the vehicle and also a small number to the central front portion only.

Front right offset impacts (FR) comprise mainly front right corner impacts (L-shape PIMP code 31) and also impacts to the right of the centre of the front of the vehicle.

Front left offset impacts (FL) comprise mainly front left corner impacts (L-shape PIMP code 30) and also impacts to the left of the centre of the front of the vehicle.

Right side centre impacts (RC) comprise mainly those impacts to the whole of the right side of the vehicle and also impacts to the central areas only.

Right front impacts (RF) comprise mainly those impacts to the front right wheel area.

Right back impacts (RB) comprise mainly those impacts to the rear right wheel area.

The **left side impact** definitions mirror those of the right side (LC, LF, LB).

Figure A2. Subdivision of vehicle surface into frontal (bold text), right side and left side impacts (and subdivisions of these) in terms of the point of impact regions coded specifically in the 1990 Fatality File (Figure A2). Note that direction of impact (also defined in Figure A2) is used only to divide the corner impacts into front and side.

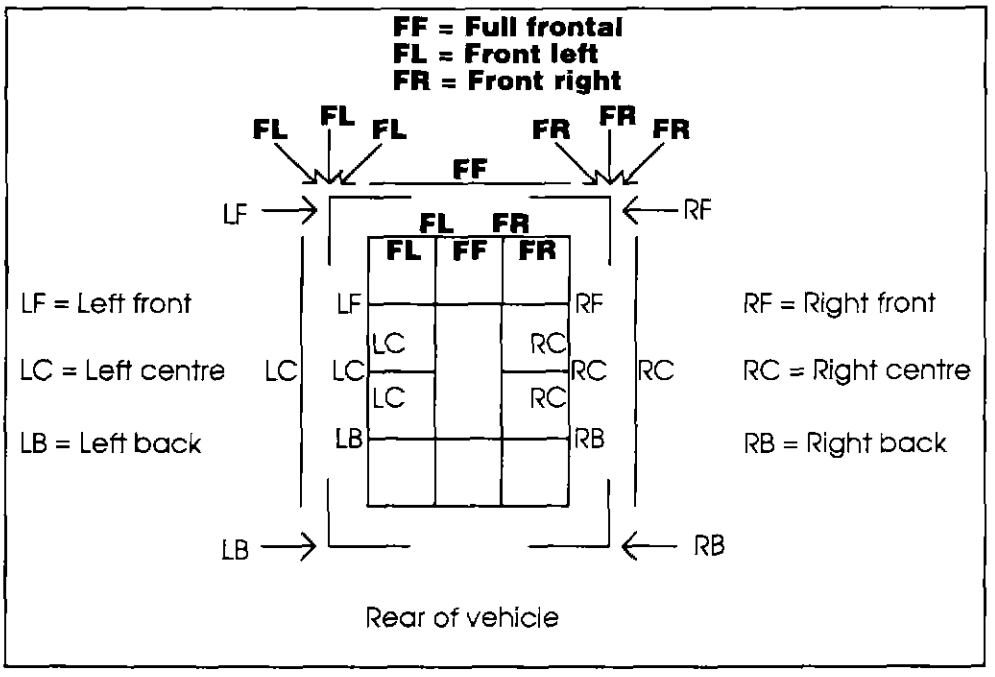


Table A1. Definition of impact types and subtypes in terms of 1990 Fatality File items PIMP and DIMP for 975 cars with impact related occupant fatalities.

Impact type	Area and direction of impact	PIMP	DIMP	# Cars
Front				**441**
Full frontal (FF)				309
	Whole of front	21	All	304
	Central portion only	19	All	5
Front right offset(FR)				85
	Front and right side from front or angle	31	1,2,3	61
	Right of centre front	18	All	20
	Front right corner	17	All	4
Front left offset (FL)				47
	Front and left side from front or angle	30	1,2,3	35
	Left of centre front	20	All	12
	Front left corner	1	All	0
Right (driver's) side				**163**
Right centre (RC)				117
	Whole of right side	24	All	83
	Centre of right side only	14	All	25
	Front of centre on right	15	All	6
	Just behind centre on right	13	All	3
Right front (RF)				39
	Front right side wheel area	16	All	35
	Front and right side from the side	31	4	4
Right back (RB)				7
	Rear right side wheel area	12	All	5
	Right side and rear from side	32	4	2
Left (passenger's) side				**170**
Left centre (LC)				141
	Whole of left side	23	All	97
	Centre of left side only	4	All	34
	Front of centre on left	3	All	9
	Just behind centre on left	5	All	1
Left front (LF)				25
	Front left side wheel area	2	All	22
	Front and left side from the side	30	8	3
Left back (LB)				4
	Rear left side wheel area	6	All	4
	Left side and rear from side	33	8	0
Other				**38**
	Rear	7-11,22	All	22
	Roof/undercarriage	25,26	All	12
	Rear and right side from rear or angle	32,33	5,6,7	4
Overturn	Fatal impact on overturn	27	-	**163**
Total				**975**