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Crashes Resulting in Car Occupant Fatalities: Side Impacts

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Abstract
This report examines data relating to all car crashes occurring in Australia in 1990 where at least one occupant fatality resulted from an impact to the side of the vehicle. In total 34% of all cars with occupant fatalities sustained a side impact, with equal numbers of such impacts occurring to the driver and passenger sides.

While side impacts were found to be more likely to occur in urban areas and involve a collision between vehicles at an intersection, this situation is far from typical. For example, 40% of all fatal crashes occur in rural areas and 59% occur mid-block (ie away from intersection)

In addition 40% of side impacts result from a collision with a fixed object such as a tree or pole rather than being hit by another vehicle.

The vast majority of side impact fatalities result from a very small number of crash types with four patterns accounting for 83% of multiple vehicle crashes and another four patterns of crashes accounting for 94% of single vehicle side impact crashes.

Although left and right impacts were equally common among vehicles with occupant fatalities, a much higher proportion of potentially lethal side impacts occur on the passenger side but generally do not result in death because the passenger side seats are often unoccupied.

Keywords
Fatalities, side impact, occupant protection, cars

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.

Table of Contents

Executive summary

This report examines data relating to all car[†] crashes occurring in Australia in 1990 where at least one occupant fatality resulted from an impact to the side of the vehicle. An earlier report (CR 138) dealt with similar data for fatal frontal impact crashes.

In total, 34% of all cars with occupant fatalities sustained a side impact, with equal numbers of such impacts occurring to the driver and passenger sides.

Characteristics of fatal side impact crashes

Compared with frontal impacts, side impact crashes are more likely to occur in urban areas, and are more likely to involve a collision between vehicles at an intersection, with only 20% of such intersections being controlled by traffic lights.

Nevertheless, this crash pattern is far from typical. Specifically, 40% of side impact crashes occur in rural areas and 59% of side impact crashes occur mid-block. In addition, 40% of all side impacts result from a collision with a fixed object such as a tree or pole rather than being hit by another vehicle - a result very similar to that obtained when frontal impacts were examined.

Lost of control on the left hand shoulder of the road was a causal factor in 19% of all fatal side impact car crashes, and 47% of side impact crashes which occurred on roads with unsealed shoulders.

Fatal side impact crashes are just as likely as fatal frontal impacts to involve drink driving and even more likely to involve excessive speed. Driver error also features more prominently compared to frontal crashes, but fatigue seems to play a less important role.

Overall, 81% of the drivers of the cars receiving the side impact were judged to be fully or partially responsible for the crash (compared with 73% of drivers of cars receiving a fatal frontal impact). When the analysis was limited to crashes where the fatal side impacts resulted from being struck by another vehicle, the driver of the struck vehicle was still judged to have been fully or partially at fault in 73% of the cases.

Car occupants killed in side impact crashes were slightly more likely to have suffered severe injuries to several body regions than those killed in frontal car crashes. For example, they were slightly more likely to have sustained severe simultaneous injuries to the head and other body regions, and less likely to have died after suffering injuries confined to the chest region.

Severe spinal injuries were detected in 8% of side impact car occupant fatalities, but only 4% for those killed in frontal impact crashes.

[†] The term *car* refers to sedans and station wagons and excludes vans, 4WD and utilities.

Comparison of *single* vehicle and *multiple* vehicle side impacts

Single vehicle side impact crashes, compared with side impacts resulting from being hit by another vehicle were more likely to occur:

- in rural areas (54% vs 31%)
- away from intersections (93% vs 36%)
- at night (61% vs 28%).

Drivers of vehicles colliding with fixed objects also were more likely to have been:

- male (76% vs 62%)
- under 25 years of age (54% vs 23%)
- not wearing a seat belt (20% vs 6%)
- engaged in drink driving, speeding or other risk taking behaviour (69% vs 28%).

In addition, vehicles involved in collisions with fixed objects were likely to have had a mass over 1300 kg (43% vs 27%).

Crash types

Although fatal side impact crashes result from a variety of crash circumstances, 87% of these crashes are accounted for by 8 basic patterns.

Multiple vehicle crashes

Although the relative mass of the striking and struck vehicles might have been expected to be less important than in the case of frontal crashes, 72% of cars sustaining a side impact were hit by either a heavier car or a larger vehicle such as a truck, bus, or 4 wheel drive. This is almost the same result as obtained when fatal multiple vehicle frontal impacts were examined. Nevertheless, the velocity of the striking vehicle was generally less than that of striking vehicles in fatal frontal crashes.

Four patterns account for 83% of multiple vehicle crashes:

1. *Through through*
   Vehicles coming from adjacent directions, both of which were going straight, collide at an intersection when one vehicle (generally the one sustaining the fatal impact) breaches right of way. In 81% of cases only passive control signals (eg stop or give way signs) existed at the intersection.

2. *Head on*
   Vehicles from opposing directions collide mid-block, generally either after the struck vehicle lost control on an unpaved shoulder or strayed into the lane of an oncoming vehicle on a curve.

3 *Through right (opposing)*
   A vehicle turning right at an intersection is hit on the passenger's side by an oncoming vehicle going straight through. The turning vehicle was typically at fault.

4. *Through right (adjacent)*
   A car at an intersection (in the majority of cases, a "T" intersection), adjacent to the stream of traffic, attempts to turn right and is hit by a vehicle on the car's right going straight. The car was typically hit on the driver's side and a majority of these drivers were at least partially at fault.

Single vehicle crashes

Single vehicle side impact crashes overwhelmingly result from collisions off the carriageway, generally involving impacts with trees or poles. Four patterns account for 94% of single vehicle side impact crashes:

1. *Off right bend*

A vehicle on a right bend leaves the carriageway; almost half of these crashes occurring after the vehicle loses control on the left hand shoulder.

2. *Off left on straight*
   A vehicle on a straight road leaves the carriageway to the left. In half of these crashes the car loses control on the road shoulder. In the remaining cases the vehicle was generally speeding on an urban road.

3. *Off right on straight*
   A vehicle on a straight road leaves the carriageway to the right. Such crashes often involved speeding on urban roads.

4. *Off left bend*
   A vehicle on a left bend leaves the carriageway, generally resulting in a driver side impact.

The incidence of left and right side impacts

The data suggest that although left and right impacts were equally common among vehicles with occupant fatalities, a much higher proportion of potentially lethal side impacts occur on the passenger side. The difference in the distribution of potential and actual lethal impacts is due to the fact that the passenger side of the vehicle is often unoccupied and impacts occurring there are therefore less likely to cause death.

The fact that there are more passenger side impacts does not, however, appear to imply an overall safety disadvantage to those occupants in that position. This is partly because it is not always only the occupant closest to the impact who dies. In addition, it appears that the driver may be at a disadvantage relative to the front passenger in rollover crashes.

Differences between actual driver and passenger side fatal impacts

Except for obvious differences in the characteristics of people killed (eg driver deaths accounted for 73% of deaths in fatal driver side impacts, but only 34% of deaths resulting from passenger side impacts), the major differences in crash characteristics between left and right impacts relate to vehicle speed and the nature of the striking vehicle.

Cars sustaining a fatal driver side impact were less likely to have been travelling over 60 kph, and, in the case of multiple vehicle crashes, were more likely to have been struck by a heavy vehicle.

1. Introduction

1.1 Objectives

This report describes crashes in which car occupants are killed as a result of impacts to the sides of their vehicles. It is the second in a series which deals with different types of collisions resulting in car occupant fatalities. The first report was concerned with frontal impacts[1].

Various aspects of the crash, the vehicles and road users involved and the injury outcome are detailed. Additionally, comparisons are made between side impact collisions with objects and side impact collisions with other vehicles, and between impacts on the left and right sides of the car.

The major data source is the FORS* 1990 Fatality File database comprising all fatal road crashes reported to police in Australia in 1990. This is supplemented with the corresponding FORS 1988 Fatality File, where necessary. Comparisons are also made with a similar database from the United States of America (FARS** 1991-93).

1.2 Report structure

Chapter 1 contains vehicle and impact definitions and the overall impact distribution. More specific details with respect to the coding are found in the Appendix.

Side impact crashes are characterised in Chapter 2. Single vehicle and multiple vehicle side impact crashes are compared in Chapter 3. Left and right side impacts are compared in Chapter 4.

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). This report concentrates on cars with occupant fatalities. For 989 of the 1657 cars involved in fatal crashes at least one occupant was killed or died within 30 days (Table 1). Cars comprise 80% of passenger vehicles with occupant fatalities (989 out of 1233).

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

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

Vehicle type	Number of occupant or 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 in this report.

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. Fifty-seven (6%) of the 989 cars with at least one occupant fatality were excluded from the analyses, since the cause of death was coded as only indirectly or not related to the crash†. A small number of cases (5) for which the exact location of the impact on the car was unknown were also excluded.

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

† This results in a smaller number of cases analysed than in the corresponding frontal impacts report, where only non-crash related deaths were excluded and indirect deaths were included.

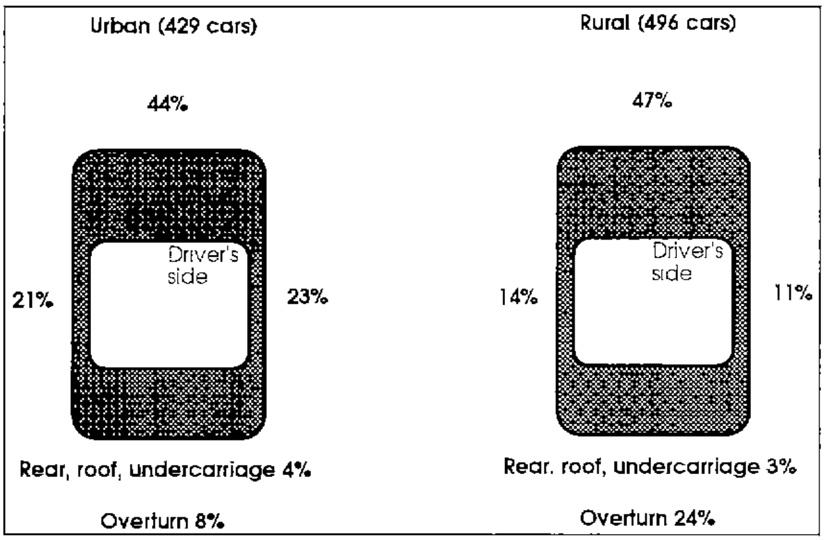
1.4 Overall impact distribution

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 (45%). There were equal numbers of right side and left side impacts (both 17%). Overturns also comprised 17%. The remaining 4% comprise impacts at the rear, on the roof and undercarriage. 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.

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

Fatal impact area	Passenger cars		Vans, 4WD, utilities, light trucks	
Front	421	45%	94	45%
Right (driver's) side	156	17%	15	7%
Left side	162	17%	11	5%
Other (rear, roof, undercarriage)	35	4%	4	2%
Overturn	153	17%	84	40%
Total vehicles	927	100%	208	100%

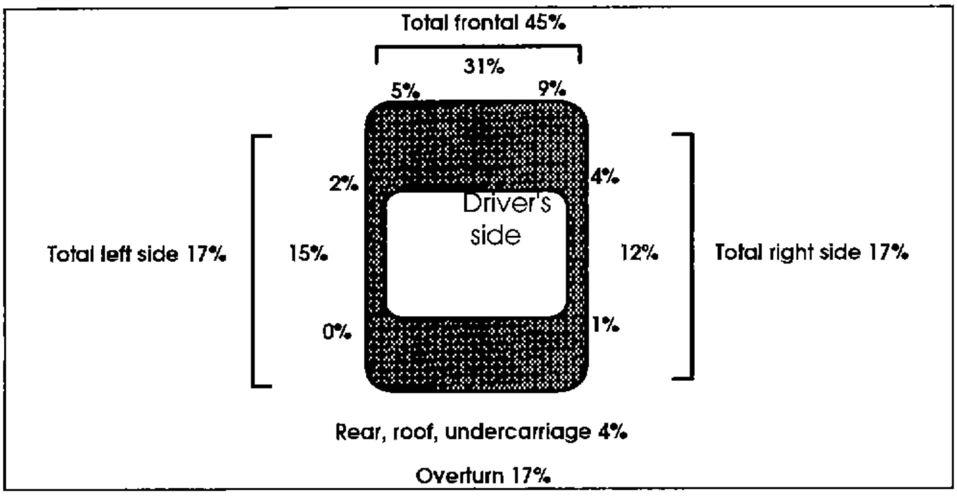
Figure 1 Impact distribution for cars with at least one direct impact related occupant fatality in urban and rural areas of Australia (1990 Fatality File)



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 (Table 2). The percentage of overturns also differs within this group; 64% 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 (22%) compared with the other passenger vehicles (52%).

The impact distribution for the 927 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 31% full frontal impacts (FF), 9% front right offset impacts (FR) and 5% front left offset impacts (FL). The component subdivisions are described in more detail in the appendix.

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

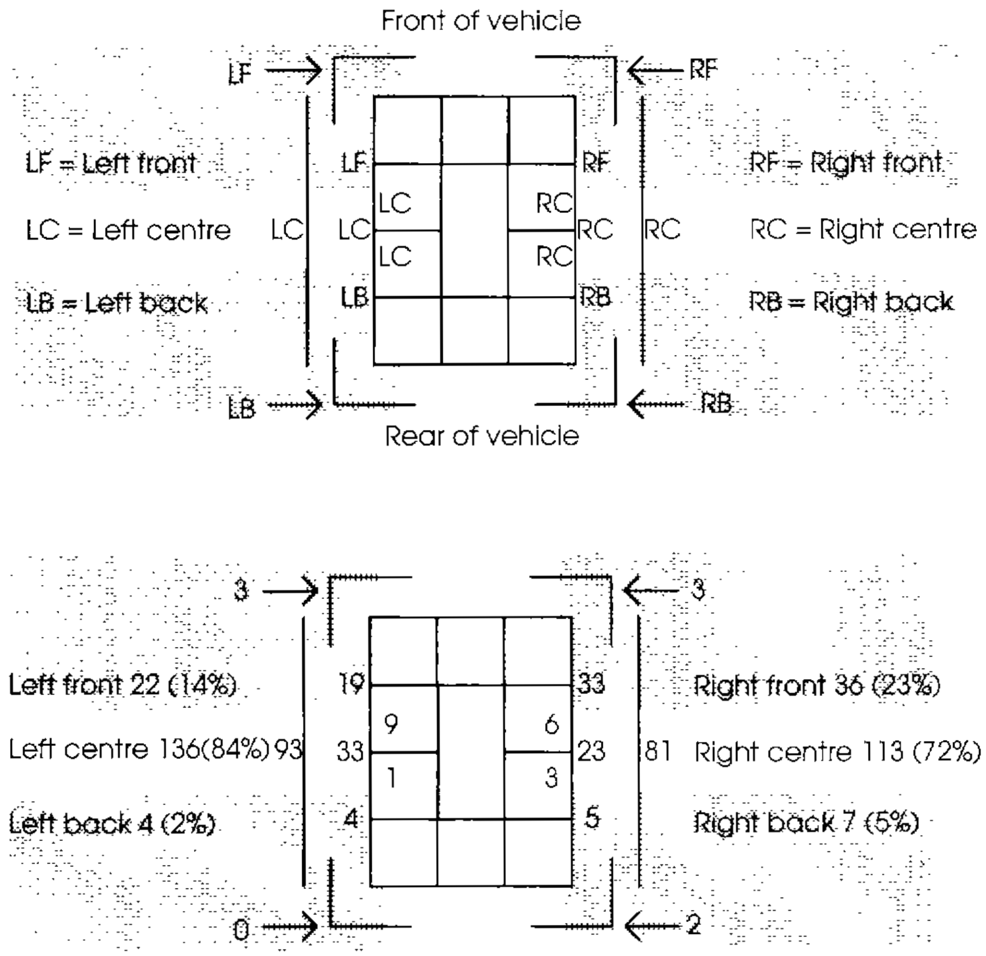


1.5 Side impacts distribution

Left and right side impacts are subdivided into central, front and rear (Figure 2). The definitions used for these six groups according to the area of the damage are indicated on Figure 3. Note that the right side corresponds to the driver's side. The bottom half of Figure 3 shows the number of cars in each of the categories. For example, a majority of the right side impacts, 113 out of 156 (72%), are classified as central (and labelled RC), and 81 of these have damage to the whole of the right hand side of the vehicle, indicated by the long vertical line on the right side of the diagram. Similarly, very few of the left side impacts are offset.

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 3). Only those L impacts for which the direction of impact is from the side are classified as side impacts.

Figure 3. Definition and number of central and offset side impacts according to primary point of impact for 318 cars with at least one direct side impact occupant fatality (FORS 1990 Fatality File) (The shaded areas indicate the codes used for the offset side impacts)



2. Characterisation of side impact crashes

This chapter describes the pre-crash setting, the crash event, the car occupant characteristics and the injury outcome for drivers and passengers involved in fatal side impacts. Both left and right side impacts are considered together in this chapter. These impacts types will be compared in a later chapter (Chapter 4).

2.1 Crash setting

The location, road configuration and driving conditions for side impact crashes resulting in car occupant fatalities are summarised in Tables 3 and 4.

Sixty percent of side impact crashes occurred in urban areas. This is higher than the corresponding percentage for frontal impact crashes (44% urban). As expected, the percentage of side impact crashes occurring in *intersections (41%) is much higher than* the corresponding percentage for frontal crashes (only 14%). This difference was observed in both urban and rural locations.

Both the percentage distributions of the different types of intersection (X, T, Y) and the presence and type of traffic controls at these crash sites were similar between frontal and side impact crashes. Almost 20% of side impact intersection crashes occurred at intersections controlled by electric lights, 24% occurred at stop signs and 28% occurred at give way signs. Only one side impact crash occurred at a roundabout. The remaining 28% occurred at intersections with no traffic controls.

Surprisingly, over half of the side impact crashes were not related to intersections. Approximately half of these non-intersection side impact crashes occurred on curved sections of road. This percentage was higher than the corresponding percentage (40%) for mid-block frontal impact crashes.

As with fatal crashes in general, a disproportionately high percentage of side impact crashes occurred on the weekend (47%), however, this was more pronounced than for fatal frontal impact crashes (Table 4). Almost sixty percent of side impact crashes occurred during the day. Interestingly, the percentage of daytime week day crashes was similar for side and frontal impact crashes. However, there was a higher percentage of *weekend* day time side impact crashes (21%) than frontal crashes (16%) (Table 4).

Table 3. The crash setting for 318 side impact crashes resulting in at least one car occupant fatality (FORS 1990 Fatality File). Percentages are also shown for 421 cars involved in fatal frontal impacts. (Shaded areas indicate percentages calculated on subsets of the data. Bolding corresponds to statistically significant differences, chi-square statistic p<.05)

Crash setting	Side impacts		Front impacts
	Crashes[†]	%	%
Location			
Urban	190	**60%**	44%
Rural	127	40%	**56%**
Speed limit			
<= 60 kph	119	**38%**	27%
65-95 kph	65	**21%**	16%
100+ kph	131	42%	**57%**
Location with respect to intersection			
Non-intersection	187	59%	**86%**
Intersection[‡]	131	**41%**	14%
Urban locations			
Non-intersection	91	48%	**75%**
Intersection	99	**52%**	25%
Rural locations			
Non-intersection	96	76%	**94%**
Intersection	31	**24%**	6%
Intersection configuration for *intersection* crashes			
X intersection	73	57%	57%
Y or T intersection	56	43%	43%
Road shoulder for *non-intersection* crashes			
Unsealed	115	68%	67%
Sealed	53	32%	33%
Horizontal road alignment for *non-intersection* crashes			
Straight	92	49%	**60%**
Curve	95	**51%**	40%
Vertical road alignment for *non-intersection* crashes			
Level	130	73%	73%
Other	47	27%	27%
Road conditions			
Dry	240	76%	82%
Wet	74	24%	18%

[†] Crashes with missing data excluded

[‡] Almost all occurred *within* the intersection. Only 2 out of 131 side impact crashes and 3 out of 421 frontal impact crashes occurred up to 10 m away from the intersection

Table 4. Time of crash for 318 side impacts resulting in at least one car occupant fatality (FORS 1990 Fatality File) Percentages are also shown for 421 cars involved in fatal frontal impacts. (Shaded areas indicate percentages calculated on subsets of the data. Bolding corresponds to statistically significant differences, chi-square statistic p<.05)

Time of crash	Side impacts Crashes	Side impacts %	Front impacts %
Time of day			
Day (6am-6pm)	186	58%	52%
Night (6pm-6am)	132	42%	48%
Time of week			
Weekday	170	53%	**61%**
Weekend†	148	**47%**	39%
Time of the day and week			
Weekday	119	37%	36%
Weekend day	67	**21%**	16%
Week-night	51	16%	**25%**
Weekend night	81	25%	23%

† Weekend defined as 6 pm Friday evening to am Monday morning

2.2 Crash event

Most crashes resulting in fatal side impacts comprised a single collision with either a vehicle or object. Only 7% involved a series of events (Table 5). Most of the multiple events involved a series of collisions (non-fatal, then fatal) and only six of the 22 multiple event side impact crashes involved a prior avoidance manoeuvre and then a fatal collision.

Sixty percent of side impacts were collisions with another moving vehicle, but in the remaining 40% the car collided with a fixed object (Table 5). A comparison of these two different types of crash is the subject of the next chapter.

In 61 (19%) of the side impact crashes, the car lost control on the left hand side shoulder of the road before the crash. In 37 of these cases, the car re-entered the carriageway after first leaving the carriageway on the left hand side. Restricting the calculation of percentages to side impact crashes on *rural* roads, the percentage with causal involvement of the shoulder is 37%. This is higher than the corresponding percentage for frontal impact crashes (14%). In almost half (47%) of the side impact crashes which occurred on roads with unsealed shoulders, loss of control on the left shoulder was noted.

Table 5. Distribution of crash event characteristics for 318 cars sustaining side impacts resulting in at least one occupant fatality (FORS 1990 Fatality File). Percentages are also shown for 421 cars involved in fatal frontal impacts. (Shaded areas indicate percentages calculated on subsets of the data. Bolding corresponds to statistically significant differences, chi-square statistic p<.05)

Crash event characteristics	Side impacts Cars	Side impacts %	Frontal impacts %
Complexity of crash			
Single event (single collision with vehicle or object)	296	93%	89%
Multiple event (prior avoidance manoeuvre or collision & subsequent fatal collision)	22	7%	11%
Object hit in fatal impact			
Another moving vehicle	191	60%	61%
Fixed object	127	40%	39%
Loss of control on left shoulder of road			
No causal involvement	256	81%	**89%**
Causal involvement of left shoulder	61	**19%**	11%
Rural locations			
No causal involvement	80	63%	**86%**
Causal involvement of left shoulder	46	**37%**	14%
Urban locations			
No causal involvement	175	92%	94%
Causal involvement of left shoulder	15	8%	6%

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, fatigue and driver error are tabulated for both fatal side and frontal impact car crashes (Table 6).

There was evidence that alcohol intoxication causally contributed to one quarter of fatal side impacts car crashes, which is similar to the involvement of alcohol in crashes resulting in fatal *frontal* impacts. This result probably underestimates the true involvement of alcohol since in a significant minority of cases (21%) no driver BAC information was obtained.

Voluntary risk taking, such as travelling at excessive speeds or performing dangerous manoeuvres, contributed to just under one third of side impacts (31%). This was a higher percentage than observed for frontal impact crashes (22%). In 75 of the 99 cases, excessive speed was involved. Twenty-three percent of the drivers of the cars sustaining the side impacts were reported to have been *definitely* over the speed limit, and an additional 7% were coded as *probably* speeding.

Combining the information on these two categories results in a total of 44% of the side impact crashes being attributable to deliberate risk taking, usually in the form of driver intoxication and/or speeding. In half of the crashes in which alcohol was a major causal factor (39 out of 80), speed was also a contributing factor.

There was also a higher incidence of driver errors among the causal factors noted for side impact crashes (20%) as compared to frontal impact crashes (11%). In 36 of the 64 side impact crashes attributed to driver error, failure to observe another other road user or signal was cited by the driver or other witness. Given the large proportion of cases in which drivers do not survive the crash, it is likely that there is considerable under-reporting of this type of causal factor.

A similar problem of underreporting exists in the detection of fatigue as a causal factor. Fatigue was noted as being at least possibly contributory in 11 of the side impacts (3%). This was lower than the corresponding percentage for frontal impact crashes (13%).

In 13 (4%) of the side impact crashes, vehicle defects were found to have contributed to the crash. In 12 of these cases, the defect was detected in the car which sustained the side impact. These defects included 5 tyre blowouts, 4 other tyre defects, one with brake problems, one with a steering defect and one other unspecified defect.

Despite the high degree of detail in the Fatality File, in 31% of the 318 side impact crashes, the road user action which caused the crash was unexplained. The corresponding percentage for frontal impact crashes was 34%.

Table 6. Incidence of causal factors contributing to 318 cars sustaining side impacts resulting in at least one occupant fatality. Frontal impacts also shown for comparison (FORS 1990 Fatality File) (Percentages do not sum to 100% since up to three causal factors may be coded for a single crash. Bolding corresponds to statistically significant differences, chi-square statistic p<.05)

Causal factors	Side impacts		Frontal impacts
	Crashes	% of 318	% of 421
Risk taking (alcohol and/or voluntary risky actions)	140	44%	40%
Alcohol (with or without other drugs)	(80)	(25%)	(28%)
Voluntary risky actions (dangerous manoeuvres, speeding)	(99)	**(31%)**	(22%)
Excessive speed	(75)	(24%)	(18%)
Driver error	64	**20%**	11%
Inattention, failure to observe other roaduser	(36)	(11%)	(5%)
Critical vehicle malfunction	13	4%	3%
Fatigue	11	3%	**13%**
Possible	(5)	(2%)	(8%)
Definite	(6)	(2%)	(5%)
Unexplained action	98	31%	34%

Driver characteristics - struck car

Just over two thirds of the drivers of cars sustaining fatal side impacts were male. Approximately one third (35%) of all drivers in the struck vehicle were under 25 years of age, but 22% were aged over 60 (Table 7). The age profile of these drivers is not different to that of drivers involved in fatal frontal impacts.

Twelve percent of the drivers of the cars struck on the side were known not to have been wearing seat belts. This figure may be somewhat of an underestimation since in 20% of cases no information about the driver's belt wearing status was available.

Just over 80% of the drivers of the cars sustaining the side impacts were at least partially at fault. This is slightly higher than the *at fault* percentage for car drivers involved in fatal frontal impacts.

Table 7. Characteristics of 316 drivers of cars sustaining a side impact resulting in at least one occupant fatality. Frontal impacts also shown for comparison (FORS 1990 Fatality File) (Bolding corresponds to statistically significant differences, chi-square statistic p<.05)*

Driver characteristics	Side impacts		Frontal impacts
	Drivers	% of 316	% of 419
Sex			
Male	213	67%	71%
Female	103	33%	29%
Age group			
<25	111	35%	36%
25-29	31	10%	11%
30-39	46	15%	17%
40-49	35	11%	11%
50-59	21	7%	6%
60+	70	22%	19%
Seat belt use			
Worn	215	68%	65%
Not worn	37	12%	16%
Not stated	64	20%	18%
Fault			
Fully at fault	246	**78%**	70%
Partly at fault	10	3%	3%
Not at fault	43	14%	**22%**
No one at fault	17	5%	5%

* For two cars with fatal side impacts, the driver was not able to be distinguished from the passengers. These vehicles are excluded from analyses of driver and passenger characteristics.

Occupants - struck car

A total of 118 of the 318 cars sustaining fatal side impacts contained just a driver and no passengers (37%). A further 34% had one passenger only and the remaining twenty-nine percent contained three or more passengers (Table 8). The most common seating position for passengers was the front left passenger seat. The rear seats tended to be occupied only if the front left passenger seat was also occupied. The rear right seat (behind the driver) was occupied in 13% of the cars and the rear left seat was occupied in 19% of the cars. The central seats were rarely occupied (Table 8).

Compared with the occupancy of cars sustaining fatal frontal impacts, cars sustaining fatal side impacts were more likely to have passengers sitting in the left front and the left rear passenger seats (Table 8).

Table 8. Seating positions of occupants of 318 of cars sustaining left or right side impacts resulting in at least one occupant fatality. The percentage distribution for frontal impacts is also shown for comparison. (FORS 1990 Fatality File) (Bolding corresponds to statistically significant differences, chi-square statistic p<.05)

Occupant details	Side impacts		Frontal impacts
	Cars	% of 318	% of 421
Number of car occupants			
1 (driver only)	118	37%	44%
2	109	34%	31%
3	51	16%	12%
4	27	9%	7%
5 or more	13	4%	5%
Most common seating combinations			
Driver only	118	37%	44%
Driver and front left passenger only	105	33%	28%
Driver, front left and rear left passenger only	27	8%	4%
Driver, front left, and rear left and rear right passenger	19	6%	4%
Driver, front left and rear right passenger only	9	3%	1%
Driver, front left and central rear passenger only	5	2%	1%
Driver, front left and rear left, central and right passenger	5	2%	2%
Other driver and passenger combination	7	2%	2%
Other in which not all seating positions exactly specified	23	7%	13%
Occupancy for each standard seating position (only for cars with *all* occupants' seating positions exactly specified)		(% of 295)	(% of 366)
Driver	295	100%	100%
Front centre	1	0%	1%
Front left	173	**59%**	47%
Rear right	38	13%	9%
Rear centre	14	5%	5%
Rear left	57	**19%**	13%

Only 7% of the front left passengers were under 17 years of age, whereas 24% of the rear seat passengers were children. Forty-seven percent of the front left passengers were within 2 years of the age of the driver. Overall, 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 of the drivers with front passengers was 40 years and the mean age of the front left passengers was 39 years. Further subdivision of the data, however, showed that male drivers tended to be, on average, two years older than their front left passengers. This was not observed for frontal impact crashes where the driver and front left passenger were of similar age regardless of the sex of the driver.

Approximately half of the passengers (both front seat and back seat) were female.

The percentage of front left passengers known not to be wearing seat belts was 11%, approximately the same as for drivers. Seat belt use was lower for rear seat passengers with 20% coded as not wearing seat belts. Seat belt use was not stated for 19% of rear seat passengers.

2.3 Crash outcome

Number of fatalities

A total of 375 persons were killed directly as a result of an impact to the side of the car in which they were travelling. In the vast majority of these crashes, there was only one car occupant killed (84%) (Table 9). Even for cars with at least 2 occupants and at least one fatality, in 74% of cases only one of the car occupants was killed.

In side impact crashes with other vehicles, it was rare that persons in the other vehicle were killed (only 3% of crashes). This is a much smaller than the corresponding percentage for fatal frontal impacts (18%).

Eleven fatal side impacts (3%) resulted in a fire or explosion. In 4 of these, at least one fatality was attributed to the fire.

Table 9. Crash outcome for occupants of 318 cars sustaining side impacts resulting in at least one occupant fatality. Frontal impact percentages shown for comparison. (FORS 1990 Fatality File) (Bolding corresponds to statistically significant differences. chi-square statistic p<.05)

Crash outcome	Side impacts		Frontal impacts
	Cars	% of 318	% of 421
Number of car occupants killed			
1	266	84%	83%
2	48	15%	15%
More than 2	4	1%	2%
Whether additional persons in other vehicles also killed			
Single vehicle crash (no other vehicles involved)	132	-	-
Multiple vehicle crash, no other persons killed	180	**97%**	82%
Multiple vehicle, at least one other person in other vehicle killed	6	3%	**18%**
Whether crash results in a fire or explosion			
No	307	97%	96%
Yes (at least one occupant died in the fire)	4	1%	2%
Yes (no occupants died as a result of the fire)	7	2%	2%

Injury outcome in different seating positions

Table 10 summarises the seating positions of the 375 car occupants killed as a result of side impacts and the 293 other occupants who survived the impact. For 38 of the occupants, there was not sufficient detail to determine their exact seating position at the time of the crash. In some of these cases it was known whether they were sitting in the back or the front of the car, but not on which side.

The 375 persons who were killed comprise 56% of the total of 668 occupants of the 318 cars sustaining the side impacts. Note that by definition at least one occupant of each car was killed. A further 28% of occupants (184 persons) were hospitalised as a result of injuries sustained in these crashes. These percentages are slightly lower than the corresponding figures for fatal frontal impacts (60% of occupants killed and 29% hospitalised).

Just under two thirds of the car drivers involved in these crashes were killed (199 out of 316, Table 10). The overall percentage of drivers killed, however, is not directly comparable with the percentage of occupants killed in the other seating positions because all the cars have a driver and, by definition, there is at least one fatality in each car. A similar argument applies to the comparison of the percentage of occupants killed on the left and right of the vehicle. Also, in this tabulation, impacts to the left and right of the car are combined. Thus, the relative safety of various seating positions cannot be inferred directly from these simple percentages.

Left and right impacts are disaggregated and compared taking into account occupancy in a later chapter.

Table 10. The number of car occupants in various seating positions and the number and percentage killed as a direct result of an impact to the side of the car (Impacts to the left and right of the car are combined) (FORS 1990 Fatality File) (The shaded region contains the five standard seating positions in a passenger car.)

	Seating position								All occupants	
	Left side (passenger's side)		Centre seat		Right side (driver's side)		Unknown side			
	Dead	Total	Dead	Total	Dead	Total	Dead	Total	Dead	Total
Front seat	114 61%	187	0 0%	1	199 63%	316	2	5	315 62%	509
Rear seat	29 46%	63	2 11%	19	20 45%	44	2	8	53 40%	134
Unknown							7	25	7	25
All occupants	143 57%	250	2 10%	20	219 61%	360	11	38	375 56%	668

Occupant fatalities

In the following tables summarising the characteristics of the car occupant fatalities, persons killed in a near side impact are distinguished from persons killed in a far side impact. The terms *near side* and *far side* refer the site of the impact relative to the seating position. For example, a near side fatality can be a driver or rear right seat passenger killed as a result of right side impact, or a front left or rear left passenger killed as a result of a left side impact. Conversely, a far side fatality is defined as a person sitting on the right hand side of the car killed as a result of an impact to the left side, or a left side passenger killed after a right side impact.

As expected, the percentage of car occupants killed in near side impacts (79%) was higher than the percentage of persons killed in far side impacts (36%) (Table 11).

Just under sixty percent of the car occupants killed in side impact crashes were male and 41% were under 25 years of age. A total of 227 (61%) were recorded as wearing a seat belt (or in a restraint) at the time of the crash, 60 (16%) were unrestrained and for 88 (23%) this information was not recorded. Excluding the missing values, the resultant percentage not wearing seat belts is 21%.

The percentage of occupants killed in a side impact crash who were trapped in the car (36%) was lower than the corresponding percentage for frontal impact fatalities (44%). Consistent with expectation, near side impact fatalities were more likely to be trapped (42%) than persons killed as a result of far side impacts (23%).

Forty-one of the 375 persons killed in side impacts were ejected from the car during the crash. Fifteen of these were not wearing seat belts at the time of the crash, 13 were coded as wearing seat belts. Seat status was unknown for the remaining 13 fatalities. The ejection rate was not statistically different for near and far side fatalities.

Table 11. Characteristics of near and far side car occupant fatalities in side impact crashes. Percentage distributions for car occupants killed in frontal impacts are also shown (FORS 1990 Fatality File) (Shaded areas indicate percentages calculated on subsets of the data. Bolding corresponds to statistically significant differences, chi-square statistic p<.05)

	Side impacts						Frontal impacts
	Near side		Far side		All[†] side impacts		
Injury severity							
Survived	71	21%	177	**64%**	293	44%	40%
Died	261	**79%**	101	36%	375	56%	60%
Characteristics of fatally injured car occupants		(261)		(101)		(375)	(507)
Sex							
Male	153	59%	54	53%	213	57%	61%
Female	108	41%	47	47%	162	43%	39%
Age group							
<17	17	7%	2	2%	22	6%	7%
17-24	89	34%	35	36%	131	35%	33%
25-39	51	20%	16	16%	70	19%	24%
40-59	38	15%	21	21%	59	16%	16%
60+	66	25%	24	25%	90	24%	21%
Seat belt/restraint							
Worn	169	65%	55	54%	227	61%	60%
Not worn	37	14%	17	17%	60	16%	21%
Not stated	55	21%	29	29%	88	23%	19%
Trapped							
No	140	58%	76	**77%**	225	**64%**	56%
Yes, trapped in car	101	**42%**	23	23%	128	36%	**44%**
Ejected (all fatalities)							
No	232	90%	89	89%	331	89%	92%
Yes, ejected from car	27	10%	11	11%	41	11%	8%
Ejected (fatalities not wearing seat belts)		(37)		(17)		(60)	(104)
No	26	70%	15	88%	45	75%	79%
Yes, ejected from car	11	30%	2	12%	15	25%	21%

[†] The total is more than the sum of near and far side fatalities since persons sitting in the centre or an unknown position are included in the total.

Injury severity and pattern

For both side impact and frontal impact crashes, over sixty percent of fatalities occurred before medical assistance arrived (Table 12).

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 location and severity for the 322 car occupants dying as a direct result of injuries received in impacts to the side of the vehicle in which they were travelling, for whom the AIS coding is available, are summarised in Table 12 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 scores 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 12.

- 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).

Although the majority of persons killed in fatal crashes sustained at least one injury coded as severe or worse, the number of severe injuries was slightly greater for persons killed in side impact crashes compared with frontal impact crashes.

Persons killed in side impacts were more likely than those killed in frontal impacts to have sustained severe injuries to more than one body region - a consequence of the statistically significantly higher incidence of head injuries (62% vs 52%) with no reduction in the proportion of severe injuries to other body regions (Table 12).

The incidence of severe spinal injuries was low, relative to head and chest injuries, but also statistically significantly higher for side impact deaths (25 cases, 8%) than for frontal impact deaths (15 cases, 4%).

The number of severe injuries, the distribution of ISS, and the location of injuries is similar for near side and far side car occupant fatalities.

Table 12. Injury severity and pattern for car occupants dying as a direct result of injuries received in impacts to the side of the car in which they were travelling. Near side and far side fatalities are distinguished and frontal impact fatalities are also shown (FORS 1990 Fatality File) (Bolding corresponds to statistically significant differences, chi-square statistic p<.05)

Fatal injury severity and pattern	Side impact fatalities: Near side fatalities		Far side fatalities		All† side impact fatalities		Frontal impact fatalities
Timing of death		(260)[1]		(99)		(372)	(500)
Instantaneous	44	17%	20	20%	67	18%	22%
Before med. attention	126	49%	39	39%	169	45%	44%
During med. attention	14	5%	4	4%	18	5%	5%
In transit	3	1%	2	2%	5	1%	4%
In hospital	73	28%	34	34%	113	30%	25%
Number[2] of severe or worse injuries (AIS 4-6)[3]		(225)		(85)		(322)	(427)
None	20	9%	7	8%	27	8%	**14%**
1	48	21%	15	18%	66	21%	25%
2	55	24%	27	32%	86	27%	24%
3	45	20%	13	15%	59	18%	19%
4+	57	25%	23	27%	84	**26%**	19%
Injury severity score (ISS)		(225)		(85)		(322)	(427)
<25	37	16%	14	16%	55	17%	20%
25-39	78	35%	31	37%	112	35%	38%
40-74	60	27%	24	28%	86	27%	23%
75	50	22%	16	19%	69	21%	19%
At least one severe injury (AIS 4-6)		(225)		(85)		(322)	(427)
Chest	150	67%	52	61%	208	65%	60%
Head	135	60%	54	64%	200	**62%**	52%
Abdomen/pelvic contents	43	19%	18	21%	61	19%	16%
Spine	14	6%	10	12%	25	**8%**	4%
Lower extremity	4	2%	2	2%	6	2%	1%
External	1	0.4%	1	1%	2	1%	1%
Neck	0	0%	1	1%	1	0.3%	1%
Upper extremity	0	0%	0	0%	0	0%	0%
Combinations of severe injuries (AIS 4-6)		(225)		(85)		(322)	(427)
Head and chest only	61	27%	18	21%	83	**26%**	22%
Head only	41	18%	22	26%	69	21%	20%
Chest only	48	21%	12	14%	61	19%	**24%**
Other region or other combination of severe injuries	22	10%	12	14%	34	11%	11%
All injuries less than AIS 4	20	9%	7	8%	27	8%	**14%**
Head and other region	19	8%	7	8%	27	**8%**	4%
Head, chest, abdomen/pelvis	14	6%	7	8%	21	7%	6%

† The total is more than the sum of near and far side fatalities since persons sitting in the centre or an unknown position are included in the total.
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 (AIS).

The relative incidence of combinations of severe injuries to various body regions are also given above. The most common pattern of severe injuries for side impact fatalities involved injuries to both the head and chest (26%).

Only a minority of people killed had all severe injuries limited to a single body region. For example, while 65% of car occupants killed in side impact crashes had at least one severe injury to the chest, less than 20% had all severe injuries confined to the chest region. Similarly, while 62% of car occupants killed in side impacts sustained at least one severe head injury, only 21% had all severe injuries confined to the head.

The high incidence severe injuries to more than one body region, particularly the head and chest, was also found in a study of fatally injured occupants in side impacts crashes in the UK in 1981-85[2]. This study also reported that far side fatalities were more likely to sustain serious head injuries than near side fatalities. Some indication of this is also seen in Table 12, with 26% of far side fatalities sustaining severe injuries only to the head and no other region, compared with only 18% for near side fatalities.

3. Differences between side impacts with other vehicles and side impacts with objects

3.1 Introduction

There are two major categories of side impact collisions; those in which the side of the car hits a fixed object, and those in which the car is hit on the side by another moving vehicle. These two different types of crashes are characterised and compared in this chapter. Many of the differences may reflect general differences between single and multiple vehicle fatal crashes. Therefore, single and multiple *frontal* impact crashes are also included for comparison.

Of the total of 318 fatal side impacts, 60% (191) were fatal collisions between a car and another vehicle. The remaining 40% (127) involved a car hitting an object. Seven side impact crashes in which a car was hit by a train are included in the former group, ie the multiple vehicle collisions. Two cases in which a prior minor collision with another vehicle caused the car to run off the road into a tree (or pole) are included in the hit object group, since the fatality occurred on impact with the tree (or pole), not the other vehicle. Despite these two exceptions, the 'hit object' crashes will generally be referred to as *single* vehicle crashes.

3.2 Crash setting

Multiple vehicle vs single vehicle side impact crashes

As expected, the multiple vehicle side impact crashes were more likely to occur within intersections than the single vehicle side impact crashes (64% vs 7%, Table 13). However, a sizeable percentage (36%) of the multiple vehicle side impact crashes were non-intersection crashes. Consistent with the higher percentage of multiple vehicle side impact crashes being intersection crashes, these crashes were also more likely than the single vehicle crashes to occur in urban areas and in the lower speed zones. Among the non-intersection crashes, the multiple vehicle side impact crashes were more likely than single vehicle crashes to occur on roads with sealed shoulders (Table 13).

The other major difference with respect to the crash setting was that the multiple vehicle side impact crashes tended to occur during the day and the single vehicle side impact crashes tended to occur at night. This was seen to be the case on both week days and weekends.

Multiple vehicle crashes: side impact vs frontal impact

The multiple vehicle side impact crashes also differed from multiple vehicle *frontal* crashes in terms of location, with relatively high percentages occurring in intersections, in urban areas and in lower speed zones. Additionally there was a higher percentage of daytime multiple vehicle side impact crashes (72%) than the corresponding daytime percentage for frontal impacts (59%).

Single vehicle crashes: side impact vs frontal impact

In general, the crash scenario for single vehicle *side* impacts and single vehicle *frontal* impacts was very similar (non-intersection, rural location, speed limit >60 kph, night time). The only difference was the relatively high percentage of non-intersection side impact crashes occurring on roads with unsealed shoulders (75% vs 59%) (Table 13).

Table 13. Crash setting for single and multiple vehicle side impact crashes resulting directly in at least one car occupant fatality. The percentage distributions for single and multiple vehicle frontal impact crashes are also shown (FORS 1990 Fatality File) (Shaded areas indicate percentages calculated on subsets of the data. Bolding corresponds to statistically significant differences between side and frontal impacts; chi-square statistic p< 05)

Crash setting	Single vehicle (hit object) crashes			Multiple vehicle crashes		
	Side impact		Front	Side impact		Front
		(127)	(164)		(191)	(257)
Location						
Urban	59	46%	48%	131	**69%**	42%
Rural	68	54%	52%	59	31%	**58%**
Speed limit						
<=60 kph	37	29%	37%	82	**43%**	20%
65-95 kph	23	18%	10%	42	22%	20%
100+ kph	66	52%	53%	65	34%	**60%**
Location regarding intersection						
Non-intersection	118	93%	90%	69	36%	**84%**
Intersection	9	7%	10%	122	**64%**	16%
Road shoulder for *non-intersection* crashes						
Unsealed	83	**75%**	59%	32	55%	**74%**
Sealed	27	25%	**41%**	26	**45%**	26%
Time of day						
Day (6am-6pm)	49	39%	40%	137	**72%**	59%
Night (6pm-6am)	78	61%	60%	54	28%	**41%**
Time of week						
Weekday	61	48%	55%	109	57%	65%
Weekend†	66	52%	45%	82	43%	35%
Time of day/week						
Weekday daytime	31	24%	25%	88	46%	43%
Weekend daytime	18	14%	15%	49	**26%**	16%
Weeknight	30	24%	30%	21	11%	**22%**
Weekend night	48	38%	29%	33	17%	19%

† Weekend defined as 6 pm Friday evening to 6 am Monday morning

3.3 Causal factors

The common causes of single vehicle crashes are alcohol and speeding (Table 14). For example, alcohol intoxication was a causal factor in half of the single vehicle side impact crashes, but in only 8% of the multiple vehicle side impact crashes. Also, speeding was coded as contributory in 43% of single vehicle side impact crashes and only 10% of multiple vehicle side impact crashes. It is interesting to note, however, that speeding was more likely for the single vehicle *side* impact crashes (43%) than for the single vehicle *frontal* impact crashes (26%)

Speeding and alcohol are often found to jointly contribute to a crash. For example, a combined category of deliberate risk taking accounts for 69% of single vehicle side impact crashes, which is much less than the sum of 51% alcohol related and 45% risky actions.

The highest rates of driver error are observed for multiple vehicle side impact crashes (27%). This percentage is high relative to the single vehicle crashes, but also higher than the corresponding figure for multiple vehicle frontal impact crashes. It should again be noted that this is probably an underestimate since witness statements are usually required in order to code such factors as inattention as causal. The high percentage of unexplained crashes (40%) probably is also related to this.

Table 14. Incidence of causal factors contributing to 318 cars sustaining side impacts directly resulting in at least one occupant fatality by crash type. Frontal impact crashes are also shown (FORS 1990 Fatality File) (Percentages do not sum to 100% since up to three causal factors may be coded for a single crash. Bolding corresponds to statistically significant differences between side and frontal impacts; chi-square statistic p<.05)

Causal factors	Single vehicle (hit object) crashes			Multiple vehicle crashes		
	Side impact		Front	Side impact		Front
		(127)	(164)		(191)	(257)
Risk taking (alcohol and/or voluntary risky action)	87	**69%**	(51%)	53	28%	(34%)
Alcohol	(65)	(51%)	(40%)	(15)	(8%)	**(20%)**
Voluntary risky actions (eg excessive speed)	(57)	**(45%)**	(27%)	(42)	(22%)	(18%)
Excessive speed	(55)	**(43%)**	(26%)	(20)	(10%)	(12%)
Driver error	12	9%	10%	52	**27%**	11%
Inattention, eg failure to observe other roaduser or signal	(2)	(2%)	(6%)	(34)	(18%)	(5%)
Critical vehicle malfunction	5	4%	2%	8	4%	4%
Fatigue	8	6%	**16%**	3	2%	**11%**
Possible	(4)	(3%)	(7%)	(2)	(1%)	(4%)
Definite	(4)	(3%)	(9%)	(1)	(1%)	(8%)
Unexplained action	21	17%	25%	77	40%	40%

3.4 Struck car details

Forty-three percent of cars sustaining fatal side impacts with objects were classified as heavy (>1300 kg). This percentage was higher than the corresponding percentages for cars involved in *multiple* vehicle side impacts, and also cars involved in single or multiple vehicle fatal *frontal* impacts (Table 15).

The high incidence of speeding among the drivers of cars involved in single vehicle collisions is consistent with the previous section on causal factors (Table 14). The results differ slightly for the multiple vehicle crashes, however, since Table 15 shows the speeding prevalence just for the drivers of the cars sustaining the fatal impact, not over all drivers involved in the crash as for Table 14.

Table 15 also shows the speed estimates, which are based on whether the drivers are speeding *and* the speed limit at the crash site. 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 is reflecting that more of the cars involved in multiple vehicle crashes are turning or pausing at intersections (63 of the 67 in the <60 kph category). 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.

The cars in the single vehicle *side* impact crashes appear to be travelling faster than the cars in the single vehicle *frontal* impact crashes. On the other hand, due to the number of side impact crashes within intersections, the estimated speeds of cars involved in multiple vehicle side impact crashes are, in general, much less than cars involved in multiple vehicle frontal impact crashes.

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

Table 15. *Characteristics of the cars sustaining side impacts directly resulting in at least one car occupant fatality by crash type. Cars sustaining fatal frontal impact are also shown. (FORS 1990 Fatality File) (Bolding corresponds to statistically significant differences between side and frontal impacts; chi-square statistic p<.05)*

Car characteristics	Single vehicle (hit object) crashes			Multiple vehicle crashes		
		Side impact	Front		Side impact	Front
		(127)	(164)		(191)	(257)
Mass of car sustaining the fatal impact						
Light (<1100 kg)	40	32%	32%	73	38%	35%
Medium (1100-1300 kg)	33	26%	**38%**	67	35%	38%
Heavy (>1300 kg)	54	**43%**	29%	51	27%	27%
Whether car sustaining fatal impact was speeding						
Unlikely	54	42%	**62%**	170	**89%**	79%
Probably	15	**12%**	7%	7	4%	**8%**
Definitely	58	**46%**	31%	14	7%	**13%**
Estimated speed* of car		(126)	(164)		(190)	(256)
<60 kph	1	1%	**3%**	67	**35%**	4%
60 kph	9	7%	**12%**	45	**24%**	13%
65-80 kph	9	7%	**12%**	20	11%	15%
85-95 kph	28	22%	20%	8	4%	5%
100 kph	39	31%	33%	38	20%	**44%**
110 kph	18	**14%**	9%	7	4%	**11%**
>110 kph	22	**18%**	**11%**	5	3%	**8%**

*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

3.5 Drivers and passengers in the struck car

The percentage of cars with passengers was similar regardless of the type of crash (Table 16).

The drivers of the cars involved in the single vehicle side impact crashes were more likely to be male, more likely to be young and less likely to be wearing a seat belt, than the drivers involved in the multiple vehicle side impact crashes. This driver profile is typical of drivers involved in single vehicle crashes, in general, although there is a higher percentage of drivers under the age of 25 (54%) compared with single vehicle *frontal* impacts (42%). It is also interesting to note that the drivers involved in the multiple vehicle side impact crashes tended to be older than drivers involved in multiple vehicle frontal impact crashes (Table 16).

Similar age patterns have previously been reported for US data by Viano *et al*[3], who compared single and multiple vehicle, side and frontal impact crashes. Their study also showed a higher percentage of older persons seriously injured or killed in side impact, car-car collisions (27% 60 years or over) compared with side impact collisions with fixed objects (only 2% 60 years or older). On the other hand (exactly as was observed in the Australian data on drivers), the percentages of older persons injured or killed in frontal impacts were intermediate to these and did not depend on whether the collisions were with another vehicle or an object.

Table 16 also shows a high percentage (73%) of drivers of the cars hit on the side by other vehicles were at least partially at fault. This percentage is higher than the corresponding percentage for drivers of cars sustaining fatal frontal impacts (61%).

Table 16. Characteristics of the occupants of cars sustaining side impacts directly resulting in at least one car occupant fatality by crash type Cars sustaining fatal frontal impacts are also shown (FORS 1990 Fatality File) (Bolding corresponds to statistically significant differences between side and frontal impacts; chi-square statistic p<.05)

Presence of passengers and driver characteristics	Single vehicle crashes			Multiple vehicle crashes		
		Side impact	Front		Side impact	Front
Number of occupants		(127)	(164)		(191)	(257)
1 (Driver only)	47	37%	42%	71	37%	45%
Driver and passengers	80	63%	58%	120	63%	55%
Sex of driver		(126)	(164)		(190)	(255)
Male	96	76%	77%	117	62%	67%
Female	30	24%	23%	73	38%	33%
Age of driver		(126)	(162)		(188)	(255)
17-24	68	**54%**	42%	43	23%	**32%**
25-39	35	28%	28%	42	22%	**27%**
40-59	17	13%	**14%**	39	21%	20%
60+	6	5%	**17%**	64	**34%**	20%
Seat belt/restraint use by driver		(126)	(162)		(188)	(255)
Worn	74	59%	54%	141	74%	73%
Not worn	25	20%	27%	12	6%	9%
Not stated	27	21%	19%	37	20%	18%
Car driver at fault		(126)	(164)		(190)	(254)
Fully or partly at fault	118	94%	92%	138	**73%**	61%
Not at fault or no one at fault	8	6%	8%	52	27%	**39%**

3.6 Multiple vehicle side impact crashes

The different types of multiple vehicle side impact crashes are summarised in Table 17. The major types are characterised by whether the crash occurred within an intersection and the direction of travel of each of the vehicles.

Although the majority of multiple vehicle crashes involved vehicles originally approaching each other from adjacent directions (especially at intersections), overall in 45% of cases the two vehicles were originally approaching each other from opposite directions.

Table 17. Crash event for 69 non-intersection and 122 intersection multiple vehicle side impact crashes directly resulting in at least one car occupant fatality (FORS 1990 Fatality File) (The primary groups are shaded)

Crash type	Non-intersection		Intersection		All locations	
Vehicles from *opposing* directions						
Head on: neither vehicle turning	52	75%	7	6%	59	31%
Through right: vehicle turning right in front of oncoming traffic	1	1%	25	20%	26	14%
Vehicles from *adjacent* directions						
Through through: both vehicles travelling straight through the intersection	0	0%	57	47%	57	30%
Through right: vehicle turning right hit by vehicle approaching intersection on right	0	0%	24	20%	24	13%
Other combination of turning vehicles	0	0%	7	6%	7	4%
Leaving driveway	5	7%	0	0%	5	3%
Hit by train	7	10%	0	0%	7	4%
Vehicles from *same* direction						
U turn	4	6%	2	2%	6	3%
All multiple side impact crashes	69	100%	122	100%	191	100%

Major types of multiple vehicle side impact crashes

Although there are many different patterns of crash events, four of these account for 83% of total multiple vehicle side impact crashes. The four major types include the 52 non-intersection '*head on*' crashes, 57 intersection '*through-through*' crashes, 25 crashes in which a vehicle turns right, in front of opposing traffic ('*through right: opposing*') and 24 crashes in which a vehicle turning right is hit by adjacent traffic ('*through right: adjacent*'). These are labelled A to D in Figure 4 and Table 18.

Side impact '*head on*' crashes (Group A)

These crashes are coded 'head on' in the sense that both vehicles are travelling in opposing directions and neither vehicle is generally intending to turn prior to the crash. However, the fatal impact occurs at the *side* of one of the vehicles. There were 52 cases of this type of crash occurring in non-intersection locations.

These crashes can be divided into those coded with causal shoulder involvement (about 29%) and those with no shoulder involvement. Typically, in the former group, the car which sustained the fatal side impact first lost control on the left shoulder of the road, re-entered the carriageway and was hit on the left hand side by the other oncoming vehicle. In most cases, it was the car which lost control which was at fault. Most of these crashes occurred on rural roads with speed limits of at least 100 kph.

In the other 37 head on side impact crashes, neither vehicle was coded as losing control on the road shoulder. Sixty percent of these occurred in urban locations. However, approximately half occurred on roads with a speed limit of at least 100 kph.

The driver of the car sustaining the fatal side impact was fully at fault (and therefore must have been in the lane of the oncoming traffic) in 60% of these head on side impact crashes with no road shoulder involvement. The impact was on the left side of the car in a large proportion of these crashes (83%) and many occurred on curves (78%). It was not possible to determine whether the road curved left or right in these cases. However, it is feasible that the car driver ended up on the wrong lane by cutting the corner on a right hand curve, or strayed onto the other lane by way of momentum on a left hand bend.

It appeared that in the small number of cases where the driver of the *other* vehicle was at fault (7), the car was more likely to sustain the fatal impact on the right hand side. However, in a further six cases neither driver was coded as being at fault and most of these impacts were on the left hand side of the car.

Speeding was a contributing factor in approximately one quarter of the 52 head on crashes. This was considerably higher than the corresponding percentage for the other major types of multiple vehicle side impact crashes discussed below. In almost forty percent of these crashes (19 out of 52), no explanation could be found for the road user action which led to the collision.

'*Through through*' intersection crashes (Group B)

There were 57 crashes involving a car and another vehicle approaching an intersection from adjacent directions, both proceeding straight through and colliding within the intersection; the car receiving a side impact resulting in at least one of the occupants being killed (Figure 4).

A majority of these crashes occurred in urban areas (Table 18). Twenty-four of these crashes occurred at stop signs, 22 at give way signs and 10 at intersections controlled by lights. Only one crash occurred at an intersection with no specific traffic control.

Figure 4. The four major types of multiple vehicle, fatal side impact crashes

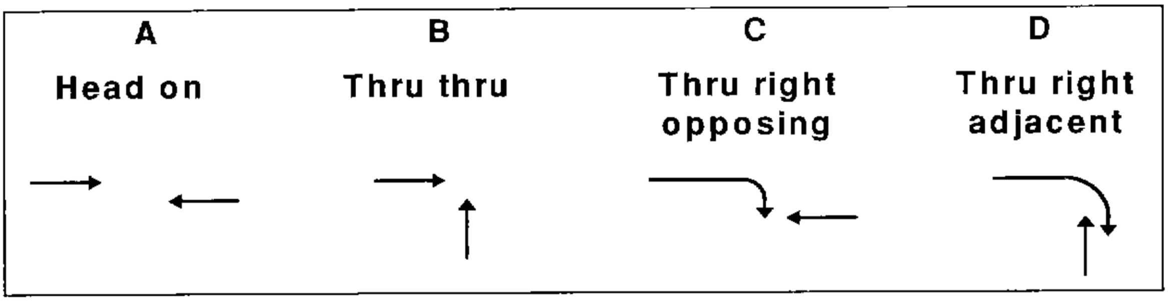


Table 18. The characteristics of the four major types of multiple vehicle, fatal side impact crashes (FORS 1990 Fatality File) (Bolding corresponds to statistically significant differences, chi-square statistic p<.05)

Crash characteristics	A *Head on* Non-intersection Opposing Neither turning		B *Through-through* Intersection Adjacent Neither turning		C *Through-right* Intersection *Opposing* 1 turning right		D *Through-right* Intersection *Adjacent* 1 turning right	
Number of crashes		(52)		(57)		(25)		(24)
Location								
Urban	27	52%	43	**77%**	21	**84%**	15	63%
Rural	25	**48%**	13	23%	4	16%	9	38%
Speed limit								
<=60 pkh	18	35%	31	**54%**	11	44%	6	26%
65-95 kph	5	10%	11	19%	7	28%	10	**43%**
100+ kph	28	**55%**	15	26%	7	28%	7	30%
Horizontal alignment								
Straight	22	42%	55	96%	25	100%	23	96%
Curve	30	**58%**	2	4%	0	0%	1	4%
Intersection controlled by:								
Lights	-	-	10	18%	11	44%	2	8%
Stop sign	-	-	22	39%	0	0%	7	29%
Give way sign	-	-	24	42%	0	0%	9	38%
None	-	-	1	2%	14	56%	6	25%
Side impact point on car with fatalities								
Right	13	25%	31	**54%**	3	12%	23	**96%**
Left	39	**75%**	26	46%	22	**88%**	1	4%
Whether driver of car at fault								
Fully at fault	33	65%	34	60%	17	68%	17	71%
Partly at fault	1	2%	3	5%	3	12%	2	8%
Other driver at fault	9	18%	19	33%	4	16%	4	17%
No one at fault	8	16%	1	2%	1	4%	1	4%

These crashes are divided up on the basis of which vehicle was at fault. In 37 crashes (65%) the driver of the car which was hit on the side was at least partially at fault. In the three cases in which the car driver was only partly at fault, the other driver was speeding. The *at fault* cars were slightly more likely to be hit on the right hand side (23 out of 37). These crashes were also slightly more likely to occur at stop signs (16 cases) or give way signs (17 cases) than at traffic lights (only 3 cases). On the other hand, when the car sustaining the side impact (and occupant fatality) was not at fault, it was slightly more likely to be hit on the left side, and there were approximately equal numbers of these cases at lights (7), stop signs (6) or give way signs (6).

Neither speeding nor alcohol were particularly prominent causal factors for any of these group B crashes. Either deliberate (10 cases), inadvertent (6) or unexplained (28) violation of traffic rules were common for these crashes.

'*Through right*' opposing direction crashes (Group C)

There were 25 crashes in which a vehicle turning right was hit by an oncoming vehicle (Figure 4, group C). In all but three of these crashes, it was the car sustaining the side impact that was turning right and the fatal impact was on the passenger's side of the car. In the other three crashes, the car was travelling straight through the intersection and was hit on the driver's side by the other vehicle which was turning right.

Most of these crashes occurred in urban locations (Table 18). Almost half of them occurred at intersections controlled by traffic lights (44%).

In all but one case, it was the driver who was turning right who was at fault. In four of these crashes, the car driver turning right was intoxicated and in a further 2 crashes there was a deliberate violation of traffic rules. Among the other 19 crashes, 7 drivers making the turn did not see the oncoming vehicle, 5 misjudged the speed of the oncoming vehicle, one misinterpreted the traffic signal, and 6 were unexplained actions (mostly ignoring the traffic control).

'*Through right*' adjacent direction crashes (Group D)

Group D is similar to group C except that the vehicles are approaching the intersection from adjacent directions (Figure 4). In almost all cases it is the car turning right which sustained a impact on the driver's hand side (Table 18). The driver of the car that was hit on the side was at least partially at fault in 79% of these crashes (Table 18).

Fifteen of these 24 crashes occurred within T intersections. Only two of the intersections were controlled by traffic lights; 9 had giveway signs, 7 had stop signs and 6 had no specific type of traffic control. Just under two thirds of these crashes occurred in urban areas. However, only 6 were in speed zones of 60 kph.

In 7 cases the car driver turning right did not see the other vehicle, in 2 cases the car driver misjudged the speed of the other vehicle. However, in 11 cases there was no explanation for the road user action which lead to the crash.

Characteristics of the striking vehicles in multiple vehicle side impact crashes

Approximately half of the side impact multiple vehicle collisions were with other cars (49%). Almost all of the rest were with larger vehicles (buses, trucks, 4WD and vans). Of the 94 collisions with another car, 43 were with cars of a heavier weight class (Table 19). Thus, only 28% of crashes were with lighter or comparable vehicles and 72% were with vehicles heavier than the car with the occupant fatalities. The corresponding percentages for frontal impacts are 23% of impacts with comparable or lighter vehicles and 77% with heavier vehicles.

The distribution of the different types of vehicles involved in side impacts with cars is consistent with that reported in a study of side impact crashes in France in 1980[4]. Expressed as percentages of *all* side impact crashes, they found 28% of side impact collisions occurred with other cars, 21% with trucks and 34% with fixed obstacles. The corresponding Australian figures for 1990 are 30%, 18% and 40%, respectively.

Table 19. Characteristics of the other vehicles impacting the sides of the cars directly causing at least one car occupant fatality in multiple vehicle side impact crashes. Frontal impacts also shown (FORS 1990 Fatality File) (Bolding corresponds to statistically significant differences, chi-square statistic p<.05)

Other vehicle	Side impacts		Frontal
Type of other vehicle involved in fatal impact with car		(191)	(257)
Car	94	49%	44%
Car of *lighter* weight class* than car sustaining fatal impact	(18)	(9%)	(11%)
Car of *same* weight class as car sustaining the fatal impact	(33)	(17%)	(12%)
Car of *heavier* weight class than car sustaining fatal impact	(43)	(23%)	(21%)
Bus/truck	56	29%	33%
Car-based utility/panel van	10	5%	5%
Four wheel drive vehicle	7	4%	9%
Ute/light truck	7	4%	5%
Forward control passenger van	7	4%	4%
Train	7	4%	0%
Motor cycle	3	2%	0%
Impact point of striking vehicle		(191)	(257)
Front	182	95%	84%
Side	8	4%	9%
Other	1	1%	7%
Whether striking vehicle speeding		(184)	(257)
No (or not noted and speed not causal factor)	171	93%	89%
Probably	1	1%	4%
Definitely	12	6%	7%
Estimated speed of striking vehicle		(182)	(257)
<60 kph	4	2%	8%
60 kph	67	**37%**	13%
65-80 kph	38	21%	19%
85-95 kph	9	5%	3%
100 kph	55	30%	**44%**
110 kph	8	4%	**9%**
>110 kph	1	1%	**4%**

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

In 95% of the multiple vehicle side impact crashes, the side of the car was hit by the front of the other vehicle (Table 19). Only 7% of the other vehicles in the crash were noted as speeding in the police report on the crash. This information is combined with the speed limit at the crash site to form a crude estimate of the speed of the striking vehicle. Approximately 39% of the vehicles making the fatal impact with the side of the car were travelling at no more than 60 kilometres an hour. This estimated speed was lower, on average than the speeds of the other vehicle in fatal frontal impacts.

3.7 Side impacts with objects (single vehicle side impact crashes)

Table 20 summarises the main features of the side impact crashes involving a car hitting an object. In most cases the car left the carriageway and the commonest objects hit were trees and poles. There were slightly more instances of cars losing control on curves rather than straight sections of road. Of the cars running off curves, almost twice as many lost control on right hand bends (42) than left hand bends (24).

In 46 of the single vehicle side impact crashes (36%), the car lost control on the left shoulder. In half of these cases, the car re-entered the carriageway before the side impact (Table 20).

Table 20 also shows the corresponding percentage distributions for single vehicle crashes in which the fatal impact is with the *front* of the car, not the side. A lower percentage of these impacts were with trees and poles and a higher percentage of these crashes occurred on the carriageway. Frontal impact crashes were also slightly less likely to occur on curves, and less likely involve the car re-entering the carriageway after losing control on the left shoulder.

Table 20. Crash event characteristics for 127 cars with side impacts into objects directly resulting in at least one occupant fatality. Single vehicle frontal impacts also shown (FORS 1990 Fatality File) (Bolding corresponds to statistically significant differences. chi-square statistic $p<.05$)

Crash event characteristics	Side impacts		Front
Object hit		(127)	(164)
Tree	72	**57%**	47%
Pole	42	**33%**	20%
Sign/rail	7	6%	**12%**
Support/culvert	3	2%	**8%**
Other (eg. animal, fence, road works materials)	3	2%	**7%**
Parked vehicle	0	0%	**6%**
Crash type			
Off path, on or after curve	67	**53%**	43%
Off path, on straight road	57	45%	46%
Lost control while overtaking	3	2%	2%
Hit object on carriageway (eg parked vehicle, animal)	0	0%	**8%**
Loss of control on left shoulder of road			
Off carriageway to left	23	18%	16%
Off left, then re-enter carriageway	23	**18%**	6%
No causal involvement; unsealed shoulder	45	35%	36%
No causal involvement; sealed shoulder or unknown if shoulder sealed	36	28%	**42%**

The single vehicle side impact collisions with objects are investigated further by characterising and comparing the main types of off carriageway crashes according to whether the crash occurred on a straight section or on a left or right curve. Four groups which account for 94% of all single vehicle side impact crashes are identified and labelled E to H; 27 crashes in which the car runs off left on a straight road, 26 crashes in which the car runs off right on a straight road, 42 crashes in which the car runs off a right hand bend and 24 crashes in which a car runs off a left hand bend (Figure 5 and Table 21).

Cars running off straight roads and hitting objects (Groups E and F)

There were approximately equally many cars running off straight sections of road to the left (group E) or to the right (group F) and, within both groups, there were approximately equally many impacts on the right and left sides of the cars (Table 21). About half of the crashes in these two groups occurred in rural and half occurred in urban locations.

Road shoulder involvement was more common for cars running off to the left. Half of the *off left* crashes were preceded by the car losing control in the left hand shoulder. These crashes tended to occur in rural locations. The other *off left* crashes with no road shoulder involvement were more likely to occur in urban locations. Speeding was more likely to be a causal factor in these crashes.

Only 6 of the 26 *off right* crashes involved a loss of control on the left hand shoulder before re-entering the carriageway and running off the right hand side of the road. All these 6 crashes were on rural roads with speed limits of at least 100 kph. The other 20 *off right* crashes (with no road shoulder involvement) were more likely to occur in urban locations. Speeding, again, was a common contributory factor.

Cars running off right and left bends and hitting objects (Groups G and H)

There were almost twice as many cars running off right hand bends (group G, 42 cars) than running off left hand bends (group H, 24 cars).

The only information relating to whether the car ran off the left or right side of the road in these crashes was with regard to loss of control on the left shoulder. Seven of the 42 cars running off right hand bends lost control on the left shoulder and probably ran off the left side. Most of these impacts were on the left side of the vehicle. Thirteen cars lost control on the left shoulder, then re-entered the carriageway and presumably left the road on the right hand side. Approximately half of these impacts were on the left and half were on the right of the car.

For the remaining 22 group G crashes, it is unknown as to whether the car ran off the left or right side of the right hand curve. It is postulated that these were more likely to run off the left side due to their forward momentum. This is supported by the fact that the majority of impacts were on the left side of the vehicle (14 out of 22). Half of these crashes occurred in urban locations.

The 24 crashes involving a car running off a left bend resulted in a majority of right side impacts (Table 21). One quarter of these crashes involved loss of control on the left hand shoulder. Right side impacts were predominant regardless of shoulder involvement.

Figure 5. The four major types of single vehicle crashes in which a car hits an object directly resulting in at least one car occupant fatality (FORS 1990 Fatality File)

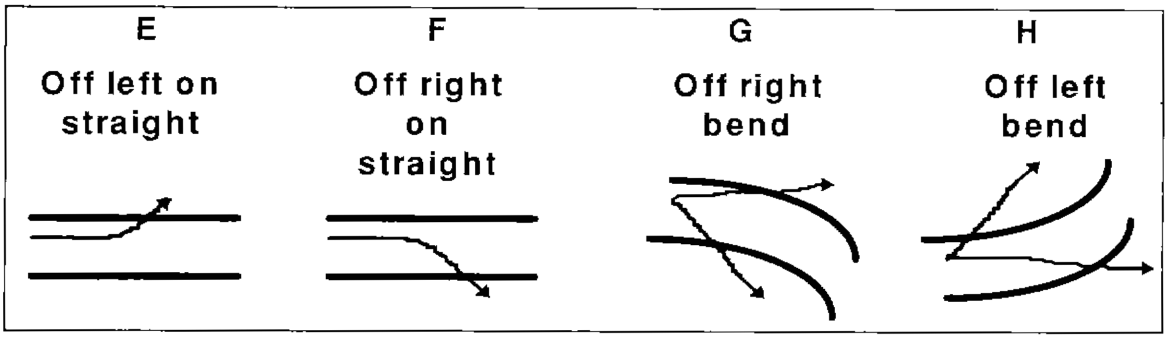


Table 21. Characteristics of the four major types of fatal side impact crashes involving fatal side impacts with objects (FORS 1990 Fatality File)

Crash characteristics	E Off *left* on *straight* road		F Off *right* on *straight* road		G Off left or right on *right* bend		H Off left or right on *left* bend	
Number of crashes		(27)		(26)		(42)		(24)
Location								
Urban	14	52%	11	42%	16	38%	13	54%
Rural	13	48%	15	58%	26	62%	11	46%
Impact location on car								
Right (driver's side)	14	52%	13	50%	17	40%	19	**79%**
Left (passenger side)	13	48%	13	50%	25	**60%**	5	21%
Loss of control on left shoulder								
Off carriageway to left	12	**44%**	0	0%	7	17%	3	13%
Off left, then re-enter	1	4%	6	**23%**	13	**31%**	2	8%
No causal involvement; unsealed shoulder	6	22%	13	50%	14	33%	12	50%
No causal involvement; sealed shoulder or unknown	8	30%	7	27%	8	19%	7	29%

Causal factors

Apart from loss of control on the left shoulder, which appeared to play a greater role in *the off left on straight* and the *off right bend* crashes, there was no evidence, on the basis of these small numbers of crashes, to suggest different causal factors between these four types of single vehicle side impact crashes. The incidence of deliberate risk taking in the form of alcohol intoxication, often coupled with driving at excessive speeds was high for all four groups.

4. Left and right side impacts

This chapter contains comparisons of left and right side impacts. The first section is concerned with estimating the distribution of left and right side impacts taking into account occupancy patterns. Corresponding data from the USA are used for comparison, as well as additional data from other Australian Fatality Files. The second section deals with differences between left and right impacts in terms of physical factors. Impacts with objects and impacts with other moving vehicles are also considered separately in this section.

4.1 Estimation of distribution of impacts

We have already seen in the Australian data that the total numbers of left side and right side impacts causing occupant fatalities are approximately equal (162 passenger's side and 156 driver's side impacts, Table 2). This does not indicate, however, that there are approximately equally many potentially fatal collisions on the left and right, since we also know that the left side of the vehicle is not always occupied. (Table 8 showed that in more than one third of the cars sustaining side impacts, the driver was the only occupant.) Thus, if it is assumed that a side impact is more likely to result in a fatality if there is a near side occupant, then the fact that there were approximately equal numbers of fatal impacts to each side of the car suggests that the number of potentially lethal impacts was greater on the passenger side.

US data

A US study by Evans and Frick[5] in 1988 used a matched-pair analysis to compare the risk of death in various seating positions relative to the driver using US FARS† data on fatal crashes for the period 1975-85. In order to exclude the possible confounding by age, sex and seat belt use on the risk of death for different occupants, the comparisons were restricted to cars with drivers and passengers, both of whom were adults (at least 16 years of age), within 3 years of age, the same sex, and neither wearing seat belts. Persons with unknown seat belt use were assumed not to be wearing seat belts.

In the FARS data, the principal point of impact on the car is coded according to a clock face with 12 o'clock being an impact to the front of the vehicle, 6 o'clock the rear, 3 o'clock the right (passenger's) side, and 9 o'clock the left (driver's) side.

The ratio of near side occupant deaths - in the American case, front passenger deaths resulting from right side impacts (3 o'clock) to driver deaths resulting from left side impacts (9 o'clock) - was found to be 1.38, interpreted as implying that 38% more potentially fatal impacts occur to the passenger's side than to the driver's side. Following Evans' estimates of the standard errors for such ratios, it is concluded that this figure is statistically significantly greater than one. Even when expanding the area of impact to include 2,3 and 4 o'clock on the right and 8, 9 and 10 o'clock on the left, the ratio remained at 1.39 (Table 22).

† FARS = Fatal Accident Reporting System

Table 22. The number and ratio (and standard error SE) of near side fatalities on the passenger's side and the driver's side for cars with at least an adult driver and front seat passenger (matched[†] on age, sex and seat belt use), at least one of whom dies in a side impact (FARS 1975-85, 1991-93)

Time period	Matching on seat belts[†]	Point of impact on car (fine or broad)	No. of near side fatalities Passengers	Drivers	Ratio (SE) Passenger/driver
1975-85	(A)Worn excluded	3 and 9 o'clock	3095	2244	1.38 (.04)
1975-85	(A)Worn excluded	2,3,4 & 8,9,10 o'clock	3883	2803	1.39 (.03)
1991-93	(A)Worn excluded	3 and 9 o'clock	376	284	1.32 (.10)
1991-93	(A)Worn excluded	2,3,4 & 8,9,10 o'clock	475	367	1.29 (.09)
1991-93	(B)Worn included	3 and 9 o'clock	547	408	1.34 (.09)
1991-93	(B)Worn included	2,3,4 & 8,9,10 o'clock	685	523	1.31 (.08)

A similar analysis was repeated on more recent FARS data (1991-93). Using exactly the same matching criteria, there were 1.32 times more the passengers killed in near side impacts than drivers killed in near side impacts (Table 22). This figure is not significantly different from that obtained with the earlier data. Both results indicate a higher incidence of fatal impacts on the passenger's side than on the driver's side for cars containing front seat occupants with similar characteristics.

Since seat belt use in the United States has increased during this period, the seat belt matching criteria were amended to include cars in which both the driver and front right passenger were wearing seat belts. This extension made no significant difference to the near side fatality ratio (1.34, Table 22).

Australian data

These near side fatality ratios from the US data were compared with corresponding numbers from the Australian fatality files. Due to the much smaller number of cases in Australia, data from the earlier Fatality File (1988), which were collected and coded in a similar manner, were included in the calculations. The definitions were also broadened slightly to include cars in which there was at least one person sitting on the right and at least one person sitting on the left, in either the front *or the rear*. Also, the matching was then between persons on the left and on the right without restriction to the front seat (ie a car was included in the matching if there was at least one person on the left and at least one person on the right of similar age, the same sex and the same seat belt use). The age difference was also relaxed to be within 6 years rather than 3 years, as used by Evans.

The near side fatality ratio for passenger deaths versus driver deaths for the combined Australian data, matched on age, sex and seat belt use, is 1.79 (Table 23). Despite the large standard error, this ratio is statistically significantly greater than unity. Due to the small numbers, however, there is not sufficient power to test whether this figure is significantly higher than the corresponding US figure 1.31 (Table 23).

Thus, both the US and the Australian data appear to suggest that the number of potentially fatal side impacts is significantly greater on the passenger side.

[†] Age matching within 3 years, same sex (ie male driver and passenger or female driver and passenger); Matching on seat belt use either
A: both not worn or unknown ie all worn excluded or
B: both worn, both not worn, or both unknown (ie worn included)

Table 23. The number and ratio (and standard error SE) of near side fatalities on the passenger's side and the driver's side for cars with at least one occupant fatality caused by a side impact and in which there were persons matched[‡] on age, sex and seat belt use on both sides of the car (FARS 1991-93, FORS 1988 and 1990 Fatality Files)

Database (cars with *matched* persons on the left and right)	Near side fatalities Passengers	Drivers	Ratio (SE) Passengers/drivers
FARS[†] (USA) 1991-1993	685	523	1.31 (.08)
FORS (Aus) 1988+1990	70	39	1.79 (.36)

This conclusion is, in turn, based on two assumptions. The first is that the matching procedure has, by controlling for occupancy and person characteristics, eliminated any differences between driver and passenger side impacts in the conditional probability of a death being recorded given that a crash has occurred. The second is that the prior probability of driver and passenger side impacts are unaffected by the matching procedures.

It is possible that the matching procedure may not have fully equalised the conditional probability of death given that an impact has taken place. For example, there may be systematic differences in the vulnerability of passengers and drivers which were not addressed by controls on age, sex, or seat belt use. On the other hand, the only unmeasured variable which has been shown to have a major effect on injury outcome, blood alcohol concentration, is unlikely to be systematically higher in passengers. Moreover, both blood alcohol concentration and other unmeasured factors are likely to be significantly correlated with the explicitly controlled variables.

The other issue which needs to be discussed is the effect of occupancy patterns on the relative number of passenger and driver side impacts, since it is possible that the controlling of occupancy and person factors has introduced its own biases. For example, it may be that the characteristics of drivers with and without passengers differ in various ways that would affect the nature of crashes in which they were involved. Even among drivers with passengers, it is known that drivers matched with their passengers on age and sex tend disproportionately to be young males and that the pattern of crashes involving this group differ in many ways from those involving other members of the population.

While the relative number of driver and passenger impacts cannot logically be investigated for vehicles without passengers, it is nevertheless interesting to consider the near side fatality ratios obtained for cars with unmatched occupants (Table 24).

The only restrictions here are that the cars sustaining the fatal side impacts must have at least one person on the right and the left of the vehicle. In both the US and the Australian data, the near side fatality ratio for the unmatched data, remains greater than unity and similar to the results obtained with matched data.

[‡] Matching in the FARS data set restricted to driver and front right passenger- age within 3 years, sex (both male or both female) and seat belt use (both wearing seat belts, both not wearing seat belts, or both unknown).
Matching on the FORS data restricted to at least one person on each side of the car within 6 years of each other, same sex and same seat belt use.
[†] Side impacts defined as driver's side (8,9,10 o'clock) and passenger's side (2,3,4 o'clock)

Table 24. The number and ratio (and standard error SE) of near side fatalities on the passenger's side and the driver's side for cars with at least one occupant fatality caused by a side impact and in which there were persons on both sides of the car (FARS 1991-93, FORS 1988 and 1990 Fatality Files)

Database (*no matching*; cars with persons on the left & right)	Near side fatalities Passengers	Drivers	Ratio (SE) Passengers/drivers
FARS† (USA) 1991-1993	3948	2966	1.33 (.03)
FORS (Aus) 1988+1990	233	151	1.54 (.16)

It is also instructive to compare impact distribution ratios for various matched sets of drivers and passengers. Results indicate that the impact ratio does not vary significantly with driver characteristics and in all cases remains greater than 1 (Table 25).

These results, while not definitive, nevertheless suggest that the finding of a greater number of passenger side impacts is relatively robust and not an artefact of the matching procedures.

Table 25. The number and ratio (and standard error SE) of near side fatalities on the passenger's side and the driver's side for cars with at least an adult driver and an adult front seat passenger (matched on age, sex and seat belt use), at least one of whom dies in a side impact (FARS 1991-93)

Driver and passenger characteristics	Near side fatalities Passengers	Drivers	Ratio (SE) Pass./driver
Total	685	523	1.31 (.08)
Sex of driver and passenger			
Male	485	361	1.34 (.09)
Female	200	162	1.23 (.13)
Age of driver (and passenger within 3 years)			
<25 years	466	352	1.32 (.09)
25-49 years	140	103	1.36 (.18)
50+ years	79	68	1.16 (.19)
Seat belt use by driver and passenger			
Not worn	381	290	1.31 (.10)
Worn	237	185	1.28 (.13)
Unknown if worn	67	48	1.40 (.26)

Why there are more passenger's side impacts

In order to understand what type of events lead to a disproportionate number of passenger side impacts, we return to the Australian data for which there is more detailed information on the crash event and circumstances. Since the asymmetry does not appear to be a function of the matching on age, sex and seat belt use, these restrictions are relaxed. However, it is necessary to retain the restriction that there must be someone sitting on the left side of the car.

† Side impacts defined as driver's side (8,9,10 o'clock) and passenger's side (2,3,4 o'clock)

The split between multiple vehicle crashes and collisions with objects is the same for left and right side impacts (61% multiple and 39% single vehicle). However, further comparisons of left and right impacts *within* these two groups of crashes reveal some interesting differences.

Collisions with other vehicles

The percentage breakdowns of the multiple vehicle side impact crashes into urban and rural areas and by speed limit did not differ significantly for right and left side impacts. The major distinctions between left and right side impacts were according to the crash event and the manoeuvres of the vehicles. As identified in the previous chapter, the side impact crashes with other vehicles again fell into four major groups (A-D, Figure 4).

There were approximately equally many left side and right side impacts among the intersection crashes in which the vehicles approached at adjacent directions and both were intending to travel straight through (group B) (Table 26). On the other hand, the non-intersection head on crashes (group A) and the intersection crashes in which the car turned right in front of an oncoming vehicle (group C) were primarily passenger side crashes.

The only type of crash which involved predominantly driver's side impacts was the relatively infrequent group D, in which two vehicles approach an intersection at adjacent directions and one vehicle, which is turning right, is hit by the other vehicle which is proceeding straight through the intersection.

The pattern of right and left side impacts was consistent in the 1988 and the 1990 Australian data for these groups. Given the different type of crash coding in FARS, all these four groups could not be identified in the US data. Nevertheless, crashes similar to groups A and B were extracted, and the patterns observed were not inconsistent with the Australian data. For example, among the mid-block multi-vehicle side impact US crashes (approximating group A), there was a greater number of passenger's side impacts (61%); and an approximately equal number of passenger's side (51%) and driver's side (49%) impacts were observed for the 'through-through' intersection crashes (group B).

Table 26. Number of fatal side impacts crashes with other vehicles for cars with at least one occupant on the right and one occupant on the left by location of impact (FORS 1988 and 1990 Fatality Files)

Multiple vehicle side impact crash type	Impact location			
(see Figure 4 in Chapter 3 for details)	Passenger side	Driver side	Total	(%)
Group A Non-intersection head on	**58**	27	85	31%
Group B Intersection 'through-through'	37	38	75	27%
Group C Intersection opposing 'through-right'	**50**	4	54	20%
Group D Intersection adjacent 'through-right'	2	**25**	27	10%
Other multiple vehicle side impact crashes	16	18	34	12%
Total multiple vehicle side impact crashes	**163**	112	275	100%

Collisions with objects

Among the crashes in which the car had a side impact with an object rather than another moving vehicle, there was a higher percentage of passenger side impacts which involved loss of control on the road shoulder. Single vehicle passenger's side impacts were also more likely than driver's side impacts to occur in rural areas.

Despite the restriction that there must be a person sitting on the right and the left of the car, and the inclusion of the earlier 1988 data, the single vehicle side impact crashes with objects fell into 4 major groups previously identified in Chapter 3 (Figure 5). One third of these crashes involved a car running off a right bend (group G), 19% involved a car running off a left bend, 22% involved a car running off a straight road to the left and 18% involved a car running of a straight road to the right (Table 27).

The small number of crashes of each type precludes detailed analysis. However, the major distinction between passenger and driver side impacts is for the crashes in which the car runs off a right hand bend. In a majority of these cases the impact is on the passenger's side. For the less frequent case of the car running off a left hand bend, however, there may be a slight predominance of driver's side impacts (Table 27).

Table 27. Number of fatal side impacts with objects for cars with at least one occupant on the right and one occupant on the left by location of impact (FORS 1988 and 1990 Fatality Files)

Single vehicle side impact crash type (see Figure 5 in Chapter 3 for details)	Impact location: Passenger side	Impact location: Driver side	Total	(%)
Group E Off straight to left	19	16	35	22%
Group F Off straight to right	17	12	29	18%
Group G Off right bend	**41**	14	55	34%
Group H Off left bend	13	18	31	19%
Other single vehicle side impact crashes	9	3	12	7%
Total single vehicle side impact crashes	**99**	63	162	100%

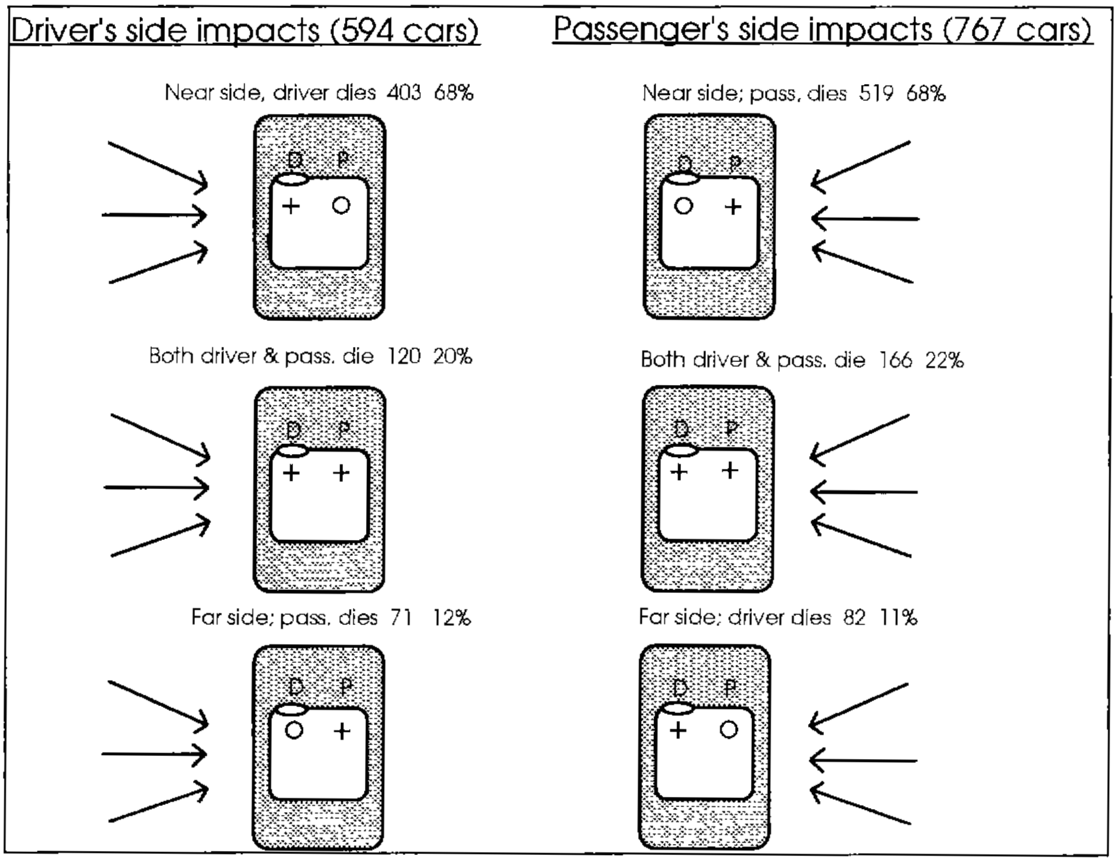
Thus, even after adjusting for occupancy, a markedly asymmetric distribution of impacts was seen in 4 of the 8 major types of side impact crashes with three of these types being more likely to result in a passenger side impact. Therefore, the disproportionate number of passenger side impacts seems to result from the fact that certain common crash patterns, by their very nature, tend to expose the passenger side of the vehicle to greater risk, and there little evidence that it is affected by specific avoidance actions (eg turning the driver's side of the vehicle away prior to the impact).

Fatality risk and seating position

The greater proportion of passenger side impacts does not necessarily imply an equivalent relative risk for drivers and passengers. This is because, while it is true that those sitting nearest to the point of impact are much more likely than far side occupants to be killed, there are many instances where this outcome is reversed or where both left and right side occupants are killed.

This is illustrated in Figure 6 which depicts the breakdown of the various combinations of front seat fatalities for left and right side impacts for the most recent (matched) FARS data. The proportion of the cars in which *both* front seat occupants die in side impacts is approximately one fifth, regardless of whether the impact is on the right or the left. However, there is a non-negligible percentage of cases where the near side occupant survives and the far side occupant dies.

Figure 6. Cars with the driver(D) and front passenger(P) matched on age, sex and seat belt use, according whether the driver and/or the passenger died in (labelled +) or survived (labelled o) a side impact to the left or right of the car (FARS 1991-93)



From the data in Figure 6 it can be calculated that, overall, there were 1.14 (876/771) times as many front seat passenger deaths as driver fatalities, suggesting that the greater number of side impacts translates into a similar, but smaller, increase in fatality risk for those in the passenger seat.

While these results suggest that occupants in passenger side seating positions are at greater risk of dying from an impact to the side of the vehicle, there appears to be no overall safety advantage when all crash types are considered. In particular, it appears that those on the driver's side are exposed to greater risk in rollover crashes. Table 28 gives the ratio of (matched) front seat passenger deaths to driver deaths for various crash impact types.

Table 28. Total number and overall ratio of front passenger and driver fatalities in cars with both front seats occupied by adults (>=16 years) matched on age (within 3 years), sex and seat belt use, at least one of whom dies, by point of impact and type of crash (FARS 1991-93)

Point of impact/type of crash	Total fatalities		Overall fatality ratio	
	Front right passengers	Drivers	Pass/driver ratio	(SE)
Front	987	957	1.03	(.05)
Side (right and left)	876	771	**1.14**	(.06)
Rear/roof /undercarriage	131	128	1.02	(.13)
Overturn	484	592	**0.82**	(.05)
Total	2478	2448	1.01	(.03)

These analyses were repeated using FARS data from the years 1982-1983 and this revealed a very similar pattern of results. These results therefore suggest that overall risk is essentially similar for front seat occupants of both positions and that this has not changed substantially over the last decade.

Similar analyses performed on the 1988 and 1990 FORS data again resulted in the same pattern, with relatively more driver's side deaths occurring in rollovers when occupancy on the left and right of the vehicle was controlled.

This was further explored in the preliminary version of the 1992 Fatality File which included additional information on the pattern of vehicle damage resulting from the rollover. Although the number of cases was limited, it was clear that occupant deaths were more likely to occur when seated on the side with the greatest vehicle damage. For example, rollover events where the primary damage was to the driver's side or driver's side and roof (presumably a result of rollovers in which the initial contact was on the driver's side) generally resulted in the death of driver's side occupants rather than passenger side occupants.

This suggests that the unequal risk of front seat occupants in rollover events reflects a tendency for vehicles to initially roll onto the driver's side.

4.2 Differences between left and right impacts: fatalities and physical factors

The previous section has shown that there are more potentially lethal passenger's side impacts than driver's side impacts. This section now examines differences between <u>actual</u> driver and passenger side fatal crashes. This is done separately for collisions with objects and collisions with other vehicles.

Fatalities in right and left side impacts

A total of 375 persons were killed in side impacts. Of these, 183 were killed in driver's side impacts and 192 were killed in passenger's side impacts. The following table shows the breakdown of the persons killed by seating position and by point of impact.

Table 29 . The number of car occupants in various seating positions and the number and percentage killed as a direct result of an impact to the side of the car (impacts to the left and right of the car are shown separately) (FORS 1990 Fatality File) (The shaded region contains the five standard seating positions in a passenger car.)

	Seating position in cars sustaining fatal **driver** side impacts								All occupants	
	Left side		Centre seat		Right side Driver's side		Unknown side			
	Dead	Total	Dead	Total	Dead	Total	Dead	Total	Dead	Total
Front seat	23 32%	73	0 -%	0	133 86%	155	1	1	157 69%	229
Rear seat	6 27%	22	1 10%	10	14 64%	22	1	3	22 39%	57
Unknown							4	15	4	15
All occupants	29 31%	95	1 10%	10	147 83%	177	6	19	183 61%	301

	Seating position in cars sustaining fatal **passenger** side impacts								All occupants	
	Left side		Centre seat		Right side Driver's side		Unknown side			
	Dead	Total	Dead	Total	Dead	Total	Dead	Total	Dead	Total
Front seat	91 80%	114	0 0%	1	66 41%	161	1	4	158 56%	280
Rear seat	23 56%	41	1 11%	9	6 27%	22	1	5	31 40%	77
Unknown							3	10	3	10
All occupants	114 74%	155	1 10%	10	72 39%	183	5	19	192 52%	367

Almost three quarters of the persons killed in right side impacts were drivers (133 out of 183, 73%). On the other hand, front left passengers only comprised 47% of persons killed in left (passenger) side impacts. In fact, drivers made up a sizeable percentage of persons killed in passenger side impacts (34%, 66 out of 192). The next largest group were rear passengers seated on the left (12%, 23 out of 192).

Rear seat passengers made up only 12% of persons killed in driver's side and 16% of persons killed in passenger's side impacts.

The characteristics of persons killed in driver's side impacts and passenger's side impacts were also compared. There was a higher percentage of males killed in driver's side impacts (64%) than passenger's side impacts (49%), presumably reflecting the larger number of drivers killed in near side impacts and the higher likelihood of a male driver.

Children comprised only 6% of persons killed in side impacts. There was a slightly higher percentage of children (aged up to 16 years) among the persons killed in passenger side impacts (8%) than driver's side impacts (4%), however, there was no statistically significant difference in the age distribution between persons killed in left and right side impacts.

Physical factors in left and right side impacts

We have seen earlier that 60% of all side impacts are collisions with other vehicles and the remainder are with other (generally fixed) road side objects. This percentage breakdown is not statistically significantly different for driver's side (57% of collisions with other vehicles) and passenger's side impacts (63% of collisions with other vehicles).

Physical factors in left and right side collisions with objects

Left and right side impacts with objects were compared in terms of the type of object hit, the estimated car travel speed and the mass of the car. None of these factors were found to vary significantly between passenger's side and driver's side impacts.

Physical factors in left and right side collisions with other vehicles

Within the class of side impact crashes with other vehicles, left and right impacts were compared in terms of the speed and mass of the car which was hit on the side, and also between the speed, type and relative mass of the other vehicle.

A car hit on the driver's side was slightly more likely to be manoeuvring or travelling at slower speeds (69% at estimated speeds of at most 60 kph) than a car hit on the passenger's side (50% at most 60 kph). The only multi-vehicle side impact crash with a predominance of driver's side impacts was the small number of group D crashes (Figure 4) in which the car turns right and is hit on the driver's side by another vehicle on the right, whereas the higher speed non-intersection head on crashes (group A) were more likely to result in passenger's side impacts.

The other major difference in the physical factors in these multiple vehicle crashes was the type of vehicle striking a car on the driver's or passenger's side. There was a much higher percentage of passenger's side impacts with other cars (60%) compared with driver's side impacts with cars (only 37%) (Table 30). Conversely, there was a higher percentage of driver's side impacts with larger vehicles such as trucks (39%), compared with passenger's side impacts (17%). Subdivision of the numbers by crash site showed that this trend was evident in both urban and rural locations.

This result was confirmed in both the 1988 FORS Fatality File and the US FARS data set (1991). In the earlier Australian data, 58% of passenger's side impacts were with cars (compared with 43% of driver's side impacts) and 34% of driver's side impacts were with trucks (compared with only 23% of passenger's side impacts). In the FARS data, the size of the difference was substantially reduced (45% of passenger's side impacts were with cars compared with 42% of driver's side impacts with cars). However, the result was still statistically significant due the much larger number of cases.

Table 30. Number of fatal impacts on the driver's side and the passenger's side of the cars by type of striking vehicle (FORS 1990 Fatality File)

Type of vehicle striking the car on the side	Fatal impact location on the car			
	Driver's side		Passenger's side	
Motor cycle	2	2%	1	1%
Car	33	37%	61	**60%**
Van/panel van/car based utility/4WD	7	8%	17	17%
Light truck	7	8%	0	0%
Rigid or articulated truck	35	**39%**	17	17%
Bus	1	1%	3	3%
Train	4	4%	3	3%
Total	89	(100%)	102	(100%)

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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 (PI) and direction of impact (DI) are the two vehicle items on which the definition is based.

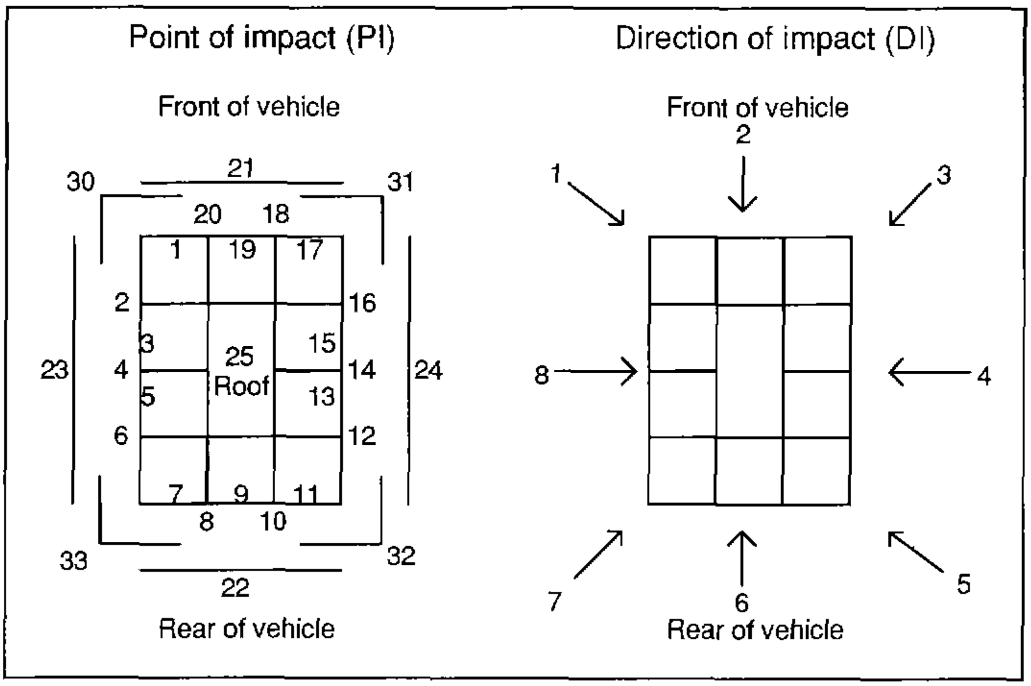
The *point* of primary impact (PI) is defined as the impact point on the vehicle which most likely caused the fatality. In the Fatality File coding scheme the surface of the vehicle is divided into 11 specific areas and other codes are allocated if the impact involved more than one of these specific 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 (DI) 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 (PI) and direction of primary impact (DI), 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 PI Fatality File codes. This is illustrated diagrammatically (Figure A2) and tabulated in Table A1. The direction of impact (DI) 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 PI 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 PI 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 area 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.

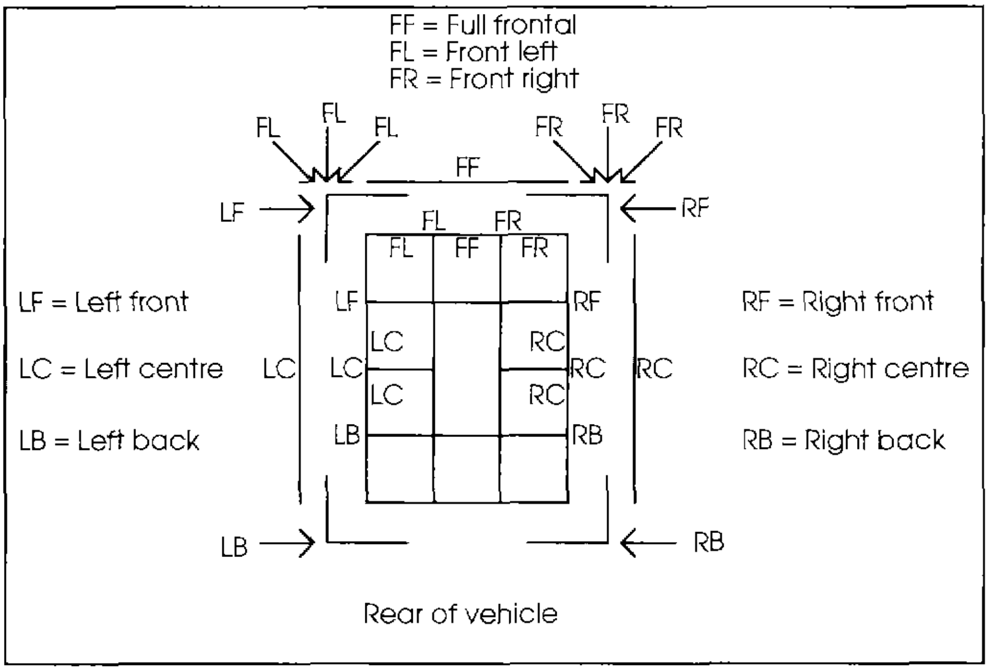


Table A1. Definition of impact types and subtypes in terms of 1990 Fatality File items PI and DI for 937 cars with direct impact related occupant fatalities.

Impact type	Area and direction of impact	PI	DI	# Cars
Front				**421**
Full frontal (FF)				292
	Whole of front	21	All	287
	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)				44
	Front and left side from front or angle	30	1,2,3	33
	Left of centre front	20	All	11
	Front left corner	1	All	0
Right (driver's) side				**156**
Right centre (RC)				113
	Whole of right side	24	All	81
	Centre of right side only	14	All	23
	Front of centre on right	15	All	6
	Just behind centre on right	13	All	3
Right front (RF)				36
	Front right side wheel area	16	All	33
	Front and right side from the side	31	4	3
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				**162**
Left centre (LC)				136
	Whole of left side	23	All	93
	Centre of left side only	4	All	33
	Front of centre on left	3	All	9
	Just behind centre on left	5	All	1
Left front (LF)				22
	Front left side wheel area	2	All	19
	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				**35**
	Rear	7-11,22	All	20
	Roof/undercarriage	25,26	All	11
	Rear and right side from rear or angle	32,33	5,6,7	4
Overturn	Fatal impact on overturn	27		**153**
Total				**927**