Vehicle compatibility:
Analysis of fatal crashes

Robyn Attewell
INTSTAT Australia Pty Ltd

Michael McFadden
Keith Seyer
FORS

CR 181

August 1999

FEDERAL OFFICE OF ROAD SAFETY
DOCUMENT RETRIEVAL INFORMATION

Report No.	Date	Pages	ISBN	ISSN
CR 181	June 1999	28	0 642 25543 1	0810-770X

Title and Subtitle

VEHICLE COMPATIBILITY:
Analysis of fatal crashes

Authors

R Attewell (INTSTAT)
M McFadden (FORS)
K Seyer (FORS)

Performing Organisation

INTSTAT Australia Pty Ltd
13b Edgar Street
AINSLIE ACT 2602

Sponsored by / Available from

Federal Office of Road Safety
GPO Box 594
CANBERRA ACT 2601

Abstract

An important determinant of the absolute level of road trauma in the population is the variance in vehicle size within the vehicle fleet, ie vehicle compatibility. This study provides estimates of relative injury risk by size of vehicle in fatal front and side impact crashes involving passenger vehicles in Australia. The results suggest that drivers and occupants in smaller vehicles are more likely to be killed in both frontal and side impact collisions with larger passenger vehicles.

Keywords

VEHICLE COMPATIBILITY, FRONTAL CRASHES, SIDE IMPACT CRASHES, MORTALITY RATIO

NOTES:

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

TABLE OF CONTENTS

EXECUTIVE SUMMARY

In recent years, the focus of vehicle designers and policy makers has extended from consideration of attributes of individual vehicles that increase the safety of their occupants to systemic features of the vehicle fleet that determine the safety of the vehicle occupant population as a whole. One important determinant of the absolute level of road trauma in the population is the variance in vehicle size within the vehicle fleet, ie vehicle compatibility.

The Federal Office of Road Safety (FORS) has put in place Australian Design Rules to improve the self-protection of occupants in frontal and side impact crashes. FORS is currently involved in international research programs to address the issue of vehicle compatibility – how to make dissimilar vehicles in the fleet provide the same level of occupant protection when they crash into one another?

While vehicle mass was previously identified as the major factor in determining injury outcomes in a two vehicle collision, more recent thinking suggests that mass is not the only factor involved, and may not be the major factor. Vehicle stiffness and geometric design are other factors that are related to vehicle compatibility.

In the last decade, small passenger cars and large 4WD vehicles have been the fastest growing sectors of passenger vehicle sales. This trend is increasing the incompatibility of the vehicle fleet and potentially raising the risk of harm to the vehicle occupant population.

To help define the degree to which vehicle compatibility is a problem in Australia, FORS has commissioned projects to examine the relative risk of injury and death of occupants in passenger vehicles of different sizes. This study provides estimates of relative injury risk in fatal front and side impact crashes involving passenger vehicles in Australia, complementing the study of casualty crashes by Les et al (1999).

The project objectives were:

- To provide frequencies of fatal frontal and side impact crashes between two passenger vehicles and between a passenger vehicle and a narrow object. This indicates the size of the potential problem.
- To provide mortality ratios for passenger vehicles involved in fatal frontal and side impact crashes according to vehicle size. This indicates the level of risk associated with vehicle compatibility.

In order to estimate the relative risk of fatal injury to occupants of passenger vehicles in various impact configurations, crude mortality ratios were calculated for each vehicle size and impact combination. The mortality ratio is defined as the ratio of the total number of deaths in one class of vehicle, defined in terms of size and point of impact, to the total number of deaths in the other vehicle. Mortality ratios were computed for drivers only (referred to as driver mortality ratios, DMR), as well as for all occupants (occupant mortality ratios, OMR). In order to adjust for possible confounding by vehicle size (due to the probable association between vehicle size and number of occupants), occupant mortality ratios were additionally adjusted for the total number of occupants in each class of vehicle.

Total passenger vehicle occupant deaths comprise 59% of the national road toll. Passenger vehicle occupants killed in crashes involving only passenger vehicles, account for 46% of all road deaths and 78% of all passenger vehicle occupant deaths.

Frontal impacts between two passenger vehicles account for 7% of all deaths. Side impacts account for a similar number (8%). Passenger vehicle impacts with a narrow object account for 12% of all deaths (6% front and 6% side). The impacts between passenger vehicles account for more deaths than impacts with narrow objects (since more persons are involved in these crashes).

There were 494 front to front fatal collisions between passenger vehicles in Australia in the four years for which detailed data on fatal crashes were available (1988, 1990, 1992 and 1994). Mortality ratio calculations are based on only 260 of these collisions, (47% are excluded due to incomplete data for size classification).

These 260 crashes resulted in 335 deaths, including the deaths of 226 drivers. A subset of 188 crashes involved vehicles of different size classes. Among these 188 crashes, 140 driver fatalities occurred in the smaller vehicles compared with only 28 driver fatalities in the larger vehicles. This results in a driver mortality ratio (DMR) of 5.0 (140/28). The corresponding occupant mortality ratio (OMR) is 4.1, based on a total of 196 occupant fatalities in the smaller vehicles and only 48 occupant fatalities in the larger vehicles. Since the total number of occupants in the smaller vehicles (373) is similar to the total number of occupants in the larger vehicles (366), adjustment for occupants doesn't substantially change the OMR(4.0)

The mortality ratios increase with increasing differentials in size. For example, for collisions involving a small car, the driver mortality ratios increase from 3.6 to 6.3 and 17.0 for collisions with medium, large and 4WD vehicles, respectively. The pattern is similar for the OMRs (2.5, 5.1 and 24.0).

The smallest mortality ratio is for collisions between medium and large cars where the DMR is 2.3 and the OMR is 1.8. This still corresponds to a doubling of the risk of death in the medium compared to the large car.

There were 574 front to side fatal collisions between passenger vehicles in the four years under study. Mortality ratio calculations are based on the subset of only 342 of these collisions for which a size classification could be made for both vehicles.

These 342 crashes resulted in 435 deaths, including the deaths of 212 drivers. As expected, more deaths occurred in the vehicles struck on the side. A total of 191 driver fatalities occurred in these vehicles, compared with only 21 driver fatalities in the vehicle striking the side of the other vehicle. This results in a driver mortality ratio (DMR) of 9.1 (191/21). The corresponding occupant mortality ratio (OMR) is 7.4, based on a total of 383 occupant fatalities in the struck vehicles and only 52 occupant fatalities in the striking vehicles. The adjusted OMR is 6.7.

Although results for side impacts are less consistent than those for frontal crashes, it does appear that the size of both the struck and the striking vehicle are important. As the size of the struck vehicle increases, the mortality ratio tends to decrease. Similarly, as the size of the striking vehicle increases, the mortality ratio increases. 4WD vehicles generate extreme results. There were 50 cases where a 4WD struck a car in the side. This resulted in no deaths in the 4WD vehicles (out of 94 occupants) and 66 occupant deaths (out of 110 occupants) in the cars.

An apparent anomaly related to large cars striking small and medium cars. The DMR for large cars into small cars (22.5) is nearly equivalent to that for large cars into medium cars (22.0). The all occupant adjusted mortality rate is much higher for large into medium than large into small.

Another anomaly relates to small cars into small cars. The DMR is high (18.0). This is similar to the DMR for large cars into small cars (22.5) and much higher than medium cars into small cars (3.3). These differences are not as evident, however, if all occupant deaths are taken into account.

Most of these inconsistencies probably relate to the very small number of deaths in the striking car. The observed mortality ratio is highly sensitive to small changes in these numbers.

Discussion

Passenger vehicle occupant deaths make up 59% of the national road toll. This corresponds to approximately 1000 fatalities in Australia, annually. The results suggest that occupant protection against a side impact (from another passenger vehicle or narrow object) is as important as frontal protection. The results also suggest that impacts with narrow objects, such as trees and poles, while not resulting in quite as many deaths as collisions between passenger vehicles, are nevertheless substantial, accounting for 21% of all passenger vehicle occupant deaths.

The mortality ratio results suggest that drivers and occupants in smaller vehicles are more likely to be killed in both frontal and side impact collisions with larger passenger vehicles. The pattern of increasing driver mortality ratios with increasing vehicle size disparity was also observed in the corresponding driver injury ratios reported for casualty crashes by Les et al (1999). However, the magnitude of the mortality ratios was considerably larger than the injury ratios. This reflects that differentials in occupant protection become increasingly important in crash situations that are severe enough to cause fatal injury (ie high speed collisions).

The role of vehicle size in fatal and injury crashes is especially relevant to Australia where the sales of small and large cars and 4WD vehicles are expanding, while sales of medium size vehicles are declining. If this continues in the long term, it will promote a vehicle fleet composition with greater size variance and therefore greater risk divergence than in the current fleet.

The current study did not (and could not) distinguish between the influence of vehicle mass, stiffness and geometric design on vehicle compatibility. It is intended to conduct further analysis to establish the relevance of these and other variables to the results reported herein.

ACRONYMS

ADR	Australia Design Rule
DMR	Driver mortality ratio
ESV	Enhanced Safety of Vehicles
FMVSS	Federal Motor Vehicle Safety Standard
FORS	Federal Office of Road Safety
IHRA	International Harmonised Research Activities
ITS	Intelligent Transport System
OMR	Occupant mortality ratio
4WD	4 wheel drive vehicle

1 Introduction

1.1 BACKGROUND

Vehicle compatibility is an issue that is foremost in the agendas of researchers worldwide – how to make dissimilar vehicles in the fleet provide the same level of occupant protection when they crash into one another? This is a complex issue for both frontal and side impact crashes.

In 1995 Australian Design Rule (ADR) 69 – Full Frontal Impact Occupant Protection was introduced. This ADR was based on US Federal Motor Vehicle Safety Standard (FMVSS) 208 except that Australia requires the dummies to be restrained. In 1999, ADR 72 was introduced for side impact protection, allowing compliance with either US or European regulations. In 2000, ADR 73 will be introduced to provide offset frontal impact protection. Together these three ADRs will provide improved self-protection for occupants of vehicles in the most common types of crashes.

A steering committee was set up at the 15th Enhanced Safety of Vehicles (ESV) Conference in Melbourne in 1996 to work towards an agreed research agenda to avoid duplication of vehicle safety research. This was the so-called International Harmonised Research Activities (IHRA) Committee that is responsible for overseeing research activities in six key areas. It was agreed at the IHRA Steering Committee meeting prior to the Windsor ESV in 1998, that Australia would take the lead role in the newly formed Side Impact Working Group. The six current IHRA Working Groups are:

1. Side impact
2. Advanced offset frontal
3. Pedestrian safety
4. Vehicle compatibility
5. Biomechanics
6. Intelligent Transport Systems (ITS).

The four occupant protection topics are linked because it is important that a solution for one doesn't jeopardise the bigger picture of vehicle compatibility. The Federal Office of Road Safety chairs and provides secretariat support for the Side Impact group and also has research projects in the other occupant protection areas.

While it is known that mass, stiffness and geometry are three important parameters in vehicle compatibility, there has been limited research to quantify the effects in the current vehicle fleet.

The US National Highway Traffic Safety Administration has initiated research into the problem of aggressive or incompatible vehicles in multi-vehicle crashes (Gabler & Hollowell, 1998). These authors note that although light trucks and vans account for over one third of registered passenger vehicles, they are involved crashes resulting in more than 50% of fatalities in light vehicle to vehicle crashes. Similarly, a study by Mizuno & Kajzer (1998) in Japan suggests that, of the passenger vehicle fleet, mini cars are the least compatible with large passenger vehicles.

Vehicle mass has previously been identified as a major factor in determining injury outcomes in a two vehicle collision (Evans, 1991). Evans suggests that as the mass of a vehicle increases, the risk to its occupants decreases, while the risk to the occupants of other vehicles increases. More recently, the Insurance Institute for Highway Safety (1998) concluded that mass is not the only factor involved and may not be the major factor. The Institute identified vehicle stiffness and geometric design as other factors related to vehicle incompatibility.

There has been little research of this type in Australia. In the last decade, small passenger cars and large 4WD vehicles have been the fastest growing sectors of passenger vehicle sales. This trend is increasing the incompatibility of the vehicle fleet and potentially raising the risk of harm to the vehicle occupant population. According to figures released by the Federal Chamber of Automotive Industries (1998), sales of small vehicles increased from 108,000 in 1988 to 183,400 in 1996 (up 70%). Similarly, 4WD sales grew from 44,600 to 81,700 (up 83%). Over the same period, all passenger vehicle sales increased by 22%.

The current study represents a preliminary analysis of the problem of vehicle compatibility in Australia. This study provides estimates of relative injury risk in fatal front and side impact crashes involving passenger vehicles in Australia, complementing the study of casualty crashes by Les et al (1999). In considering the issue of side impacts between passenger vehicles, the study also considered the occurrence of side impacts with narrow objects.

1.2 PROJECT OBJECTIVES

The project objectives were:

- To provide frequencies of fatal frontal and side impact crashes between two passenger vehicles and between a passenger vehicle and a narrow object. This indicates the size of the potential problem.

- To provide mortality ratios for passenger vehicles involved in fatal frontal and side impact crashes according to vehicle size. This indicates the level of risk associated with vehicle compatibility.

2 Methodology

2.1 DATA SOURCE

Data from the FORS Fatality File 1988, 1990, 1992 and 1994 were analysed. The FORS Fatality File is an extensive database compiled from coronial investigations into fatal road crashes[1] in Australia. The years 1988, 1990, 1992 and 1994 are the most recent years for which data coding has been finalised. No collections were made in the intervening years. The crashes reported in the FORS Fatality File comprise 98% of fatal crashes known to have occurred in the collection years[2]. The crash records for the remainder are missing due either to protracted legal proceedings arising from the crash or to local administrative procedures, where the file has been dissolved before being made available to the Federal Office of Road Safety (FORS).

A coroner's report into a fatal crash typically contains:
- the coroner's finding,
- police reports,
- vehicle inspection reports,
- eyewitness statements,
- photographs of the vehicles involved and the crash scene,
- autopsy details,
- toxicology reports, and
- expert witness statements, where these were required.

These documents are coded by trained coders into a standard crash report form according to specifications supplied by FORS. Data consistency and quality is maintained through double coding of key fields and regular audits of the coding process.

In summary, the data are highly representative of fatal road crashes occurring in Australia.

The fatal file contains data items relating to the crash, the vehicles involved and all persons involved. Variables of interest to the current study include:
- Crash configuration
- Primary impact location on each vehicle involved
- Make and model of vehicles involved
- Year of manufacture of vehicles involved
- Types of objects involved in the collision
- Injury outcomes for all occupants
- Occupant seating position.

[1] A fatal crash is any road crash that results in the death of a person within 30 days of the crash, from injuries sustained in the crash.

[2] For the four years under study (1988, 1990, 1992 and 1994), coroner's records were available for 7880 fatal road crashes in which 8934 people were killed. There was a total of 8060 known fatal crashes in those years, with 9120 deaths (Federal Office of Road Safety, 1998).

2.2 DEFINITIONS

Passenger vehicles

The analysis was restricted to crashes involving passenger vehicles, which can be broadly described as cars and 4WD vehicles. More specifically, passenger vehicles include:

- Sedans
- Sports cars
- Coupes
- Station wagons
- Hatchbacks
- Panel vans
- Utilities based on car design (eg Ford and Holden)
- 4WD vehicles.

This definition of passenger vehicles excludes:

- Forward control passenger vans
- Utilities based on truck design (including dual cab utilities)
- Light trucks
- Motor cycles
- Heavy vehicles (buses and rigid and articulated trucks)

Vehicle size

Passenger vehicles were divided into 4 size categories based on mass and vehicle type: small, medium, large and 4WD. This was determined by FORS based on information on new car specifications supplied as part of compliance plate approval applications (Table 1 and Appendix A). The actual mass of vehicles involved in crashes is not specifically coded in the Fatality File. The classification of vehicles in this study was based, instead, on the broad classification of body type (sedan, station wagon, utility, 4WD), make, model and year of manufacture of the vehicle. A total of 28% of passenger vehicles could not be classified according to size due to incomplete coding of these data items in the Fatality File. Excluding these, the relative frequency distribution of small, medium, large cars and 4WD vehicles involved in fatal crashes is 35%, 20%, 36% and 8%, respectively.

The classification of *small* passenger vehicle in this report corresponds to a combination of the two classifications, *light* (<=900 kg) and *small* (901-1151 kg) in the casualty crash study by Les et al (1999). The small number of fatal crashes relative to casualty crashes precluded further disaggregation in this study. The medium, large and 4WD categories are the same in the two reports.

Table 1. Size classification of passenger vehicles based on mass and vehicle type

		Examples					
Group	Mass, kg	Ford	Holden	Mazda	Mitsubishi	Nissan	Toyota
Small	<=1150	Festiva	Nova	121	Colt	Pulsar	Corolla
Medium	1151-1300	Telstar	Camira	626	Scorpion	Stanza	Camry <1993
Large	>1300	Falcon	Commodore	929 1987+	Magna	Skyline	Camry 1993+
4WD	Various	Maverick	Jackaroo	-	Pajero	Patrol	Landcruiser

Note: More details in Appendix A

Impact location and crash type

Impacts were classified according to the point of primary impact coded in the Fatality File. This is the location of the impact considered to have caused the fatality. Crashes resulting in only frontal and/or side impacts were included in the analysis. The areas of the vehicle defined as the side and the front are detailed in Appendix B.

Four major collision types were analysed:
Vehicle to vehicle collisions
1. Front to front (head on) collisions (referred to as frontal impacts)
2. Front to side collisions (referred to as side impacts)

Single vehicle collisions
3. Frontal impacts with an object
4. Side impacts with an object

Objects hit in single vehicle crashes

Crashes of interest in this study included only frontal and side impacts with other passenger vehicles and frontal and side impacts with narrow fixed objects. The definition of narrow fixed objects includes poles, signs, posts and trees. Single vehicle crashes with other objects, such as parked vehicles or animals or unspecified objects, were excluded.

Mortality ratio

In order to estimate the relative risk of fatal injury to occupants of passenger vehicles in various impact configurations, crude mortality ratios were calculated for each vehicle size and impact combination in vehicle to vehicle collisions. The mortality ratio is defined as the ratio of the total number of deaths in one class of vehicle, defined in terms of size and point of impact, to the total number of deaths in the other vehicle. To aid interpretability by generally ensuring that the ratio is greater than one, the 'other' vehicle (forming the denominator of the ratio) was typically defined as the larger vehicle in front to front impacts and defined as the vehicle with the frontal impact in the front to side collisions (ie the striking vehicle).

Mortality ratios were computed for drivers only (referred to as driver mortality ratios and denoted DMR), as well as for all occupants (occupant mortality ratios, OMR). In order to adjust for possible confounding by vehicle size (due to the probable association between vehicle size and number of occupants), occupant mortality ratios were additionally adjusted for the total number of occupants in each class of vehicle (OMR_{adj}). This was achieved by dividing the total number of deaths in each class of vehicle by the total number of occupants in each class of vehicle before computing the ratio.

The driver mortality ratios correspond directly to the relative injury risk measure used in the non-fatal casualty crash study by Les et al (1999), except that fatal injury is the only injury considered.

3 FINDINGS

3.1 Frequency distributions

Passenger vehicle occupant deaths in relation to the national road toll

The relative distribution of the different types of road crashes resulting in fatalities in the four years under study is given in Table 2. Total passenger vehicle occupant deaths comprise 59% of the national road toll. Passenger vehicle occupants killed in crashes involving only passenger vehicles, account for 46% of all road deaths and 78% of all passenger vehicle occupant deaths.

Frontal impacts between two passenger vehicles account for 7% of all deaths. Side impacts account for a similar number (8%). Passenger vehicle impacts with a narrow object account for 12% of all deaths (6% front and 6% side). The impacts between passenger vehicles account for more deaths than impacts with narrow objects (since more persons are involved in these crashes).

All subsequent analysis is restricted to fatal frontal and side impact crashes involving only passenger vehicles or passenger vehicles hitting narrow objects

Table 2. Composition of fatal crashes, Australia 1988, 1990, 1992 and 1994

Crash type	Crashes		Deaths	
All fatal crashes	*7880*	*100%*	*8934*	*100%*
Only passenger vehicles involved	*3502*	*44%*	**4102*	*46%*
Front-front impacts between vehicles	494	6%	653	7%
Front-side impacts between vehicles	574	7%	707	8%
Front impact with narrow object	489	6%	562	6%
Side impact with narrow object	469	6%	531	6%
Other impacts eg rollover, read end crash	1476	19%	1649	18%
Passenger vehicle involved with other vehicle/pedestrian	*2739*	*35%*	***3037*	*34%*
No passenger vehicles involved	*1639*	*21%*	*1795*	*20%*

*All deaths are passenger vehicle occupants.
**Includes 1133 deaths of passenger vehicle occupants.
Source: FORS Fatality Files 1988, 1990, 1992 and 1994

Fatal frontal and side impacts involving passenger vehicles

There is approximately the same number of fatal crashes involving frontal impacts between passenger vehicles, frontal impacts with a narrow object and side impacts with a narrow object. There were slightly more fatal crashes involving side impacts between passenger vehicles (Table 3).

Impacts with narrow objects account for 45% of occupant deaths, when restricted to frontal and side impact passenger vehicle crashes (1093/2453, Table 3) or 21% of occupant deaths overall (1093/(4102+1133), Table 2)

Table 3. Composition of fatal frontal and side impacts involving passenger vehicles, Australia1988, 1990, 1992 and 1994

Crash type	Crashes		Deaths	
Only passenger vehicles involved	*2026*	*100%*	*2453*	*100%*
Vehicle to vehicle crashes				
Front-front impacts between vehicles	494	24%	653	27%
Front-side impacts between vehicles	574	28%	707	29%
Single vehicle crashes				
Front impact with narrow object	489	24%	562	23%
Side impact with narrow object	469	23%	531	22%

Source: FORS Fatality Files 1988, 1990, 1992 and 1994

3.2 Mortality ratios for vehicle to vehicle crashes

Frontal impacts

There were 494 front to front fatal collisions between passenger vehicles in Australia in the four years considered (Table 3). Mortality ratio calculations are based on only 260 of these collisions, (234 were excluded due to incomplete data for size classification for either or both vehicles, 47%).

These 260 crashes resulted in 335 deaths, including the deaths of 226 drivers. A subset of 188 crashes involved vehicles of different size classes. Among these 188 crashes, 140 driver fatalities occurred in the smaller vehicles compared with only 28 driver fatalities in the larger vehicles. This results in a driver mortality ratio (DMR) of 5.0 (140/28). The corresponding occupant mortality ratio (OMR) is 4.1, based on a total of 196 occupant fatalities in the smaller vehicles and only 48 occupant fatalities in the larger vehicles. Since the total number of occupants in the smaller vehicles (373) is similar to the total number of occupants in the larger vehicles (366), adjustment for occupants doesn't substantially change the $OMR_{adj} = 4.0 = (196/373)/(48/366)$.

The relative frequency distribution of the 260 front-front collisions between passenger vehicles of various size classes is given in Table 4a. For example, small cars were involved in 151 crashes, 34 frontal impacts with other small cars and 117 frontal impacts with larger passenger vehicles. There were at least 10 individual fatal crashes in each pairwise combination, except for impacts between 4WD vehicles (for which there was only one case).

Table 4a. No. of front to front fatal collisions between passenger vehicles of various sizes, Australia 1988, 1990, 1992, 1994

	Size of other vehicle				Total
	Small	Medium	Large	4WD	crashes
Size of subject vehicle					
Small	**34**	35	61	21	117
Medium	35	**10**	39	11	50
Large	61	39	**27**	21	21
4WD	21	11	21	**1**	0
Total crashes	151	95	148	54	260*

Source: FORS Fatality Files 1988, 1990, 1992 and 1994
Shaded cells represent impacts where the subject vehicle is smaller than the other vehicle.
Bolded figures represent impacts between vehicles of the same size class.
* total crashes (no double counting)

The corresponding mortality ratios for these combinations are given in Table 4b and Figure 1. For example, the driver mortality ratio for small cars vs medium cars is 3.6, ie 3.6 more drivers of small cars are killed compared with drivers of medium cars in head on collisions between these vehicles. This estimate is based on 35 fatal crashes. It should be noted that the inverse of this number 0.3 (1/3.6) is also listed in Table 4b (in the diagonally opposite position) corresponding to the DMR for medium cars vs small cars. Further details of total fatality and occupant counts for each crash combination are in Appendix C (Table C1).

All ratio estimates for the combinations where the subject vehicle is smaller than the other vehicle are greater than one (shaded region of Table 4b). This is the case even for frontal collisions between large passenger vehicles and 4WD vehicles. This indicates that the driver and the occupants of the smaller vehicle are more likely to be killed than the driver and occupants of the larger vehicle in a front to front collision.

The mortality ratios increase with increasing differentials in size (Figure 1). For example, for collisions involving a small car the driver mortality ratios increase from 3.6 to 6.3 and 17.0 for collisions with medium, large and 4WD vehicles, respectively. The pattern is similar for the OMRs (2.5, 5.1 and 24.0) (Table 4b).

The smallest ratio for vehicles of different size is for collisions between medium and large cars, where the DMR is 2.3 and the OMR is 1.8. This still corresponds to a doubling of the risk of death in the medium compared to the large car.

There were 53 frontal crashes between cars and 4WDs resulting in 5 deaths in the 4WD vehicles and 64 deaths (of 116 occupants) in the cars (OMR = 12.8) (Table C1).

Table 4b. Relative fatal injury risk in front to front collisions between passenger vehicles of various sizes estimated by driver mortality ratios (DMR) and occupant mortality ratios with and without adjustment for number of occupants (OMR_{adj} and OMR)

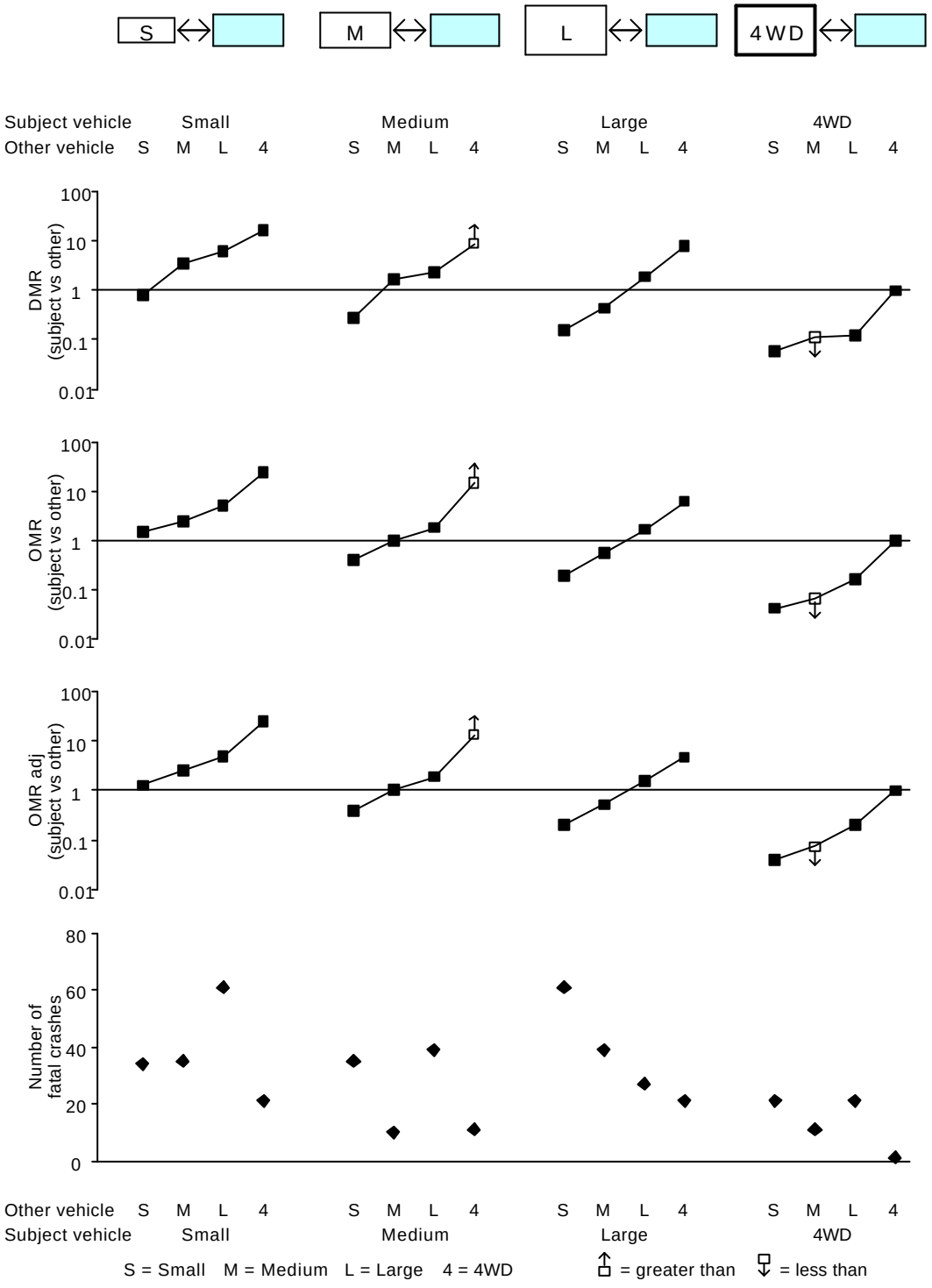
DMR (subject vs other)	Size of other vehicle				Total
	Small	Medium	Large	4WD	
Size of subject vehicle					
Small	**0.8**	3.6	6.3	17.0	5.8
Medium	0.3	**1.7**	2.3	>9.0*	3.2
Large	0.2	0.4	**1.9**	8.0	8.0
4WD	0.06	<0.1	0.1	**1.0**	
Total					5.0

OMR (subject vs other)	Size of other vehicle				Total
	Small	Medium	Large	4WD	
Size of subject vehicle					
Small	**1.5**	2.5	5.1	24.0	4.6
Medium	0.4	**1.0**	1.8	>15.0*	2.7
Large	0.2	0.5	**1.7**	6.3	6.3
4WD	0.04	<0.1	0.2	**1.0**	
Total					4.1

OMR_{adj} (subject vs other)	Size of other vehicle				Total
	Small	Medium	Large	4WD	
Size of subject vehicle					
Small	**1.3**	2.6	5.0	25.2	4.7
Medium	0.4	**1.1**	1.9	>13.7*	2.8
Large	0.2	0.5	**1.6**	4.8	4.8
4WD	0.04	<0.1	0.2	**1.0**	
Total					4.0

Source: FORS Fatality Files 1988, 1990, 1992 and 1994
Shaded cells represent impacts where the subject vehicle is smaller than the other vehicle.
Bolded figures represent impacts between vehicles of the same size class. The subject vehicle was chosen at random.
DMR = #drivers killed in subject vehicles/#drivers killed in other vehicles
OMR = #occupants killed in subject vehicles/#occupants killed in other vehicles
OMR_{adj}= (#occupants killed/#occupants in subject vehicles)/(#occupants killed/#occupants in other vehicles)
*DMR = 9/0 OMR = 15/0 OMR_{adj} = (15/23)/(0/21)

Figure 1. Relative fatal injury risk in front to front collisions between passenger vehicles according to vehicle size estimated by driver mortality ratios (DMR) and occupant mortality ratios with and without adjustment for number of occupants (OMR_{adj} and OMR)



Source: FORS Fatality Files 1988, 1990, 1992 and 1994

Side impacts

There were 574 front to side fatal collisions between passenger vehicles (Table 3). Mortality ratio calculations are based on the subset of 342 of these collisions for which a size classification could be made for both vehicles.

These 342 crashes resulted in 435 deaths, including the deaths of 212 drivers. As expected, more deaths occurred in the vehicles struck on the side. A total of 191 driver fatalities occurred in these vehicles, compared with only 21 driver fatalities in the vehicle striking the side of the 'subject' vehicle. This results in a driver mortality ratio (DMR) of 9.1 (191/21). The corresponding occupant mortality ratio (OMR) is 7.4, based on a total of 383 occupant fatalities in the struck vehicles and only 52 occupant fatalities in the striking vehicles. The adjusted OMR is 6.7 (Table 5b and Appendix C Table C2).

The relative frequency distribution of the 342 front into side collisions between passenger vehicles of various size classes is given in Table 5a. Crash combinations between vehicles of the same size class are included, since the occupant protection in a side impact is expected to be less even when the striking vehicle is the same size class as the struck vehicle. The vehicle impacted on the side is referred to as the struck vehicle. The vehicle referred to as the striking vehicle is the vehicle with a frontal impact. For example, there were 33 fatal collisions in which the front of a small car hit the side of another small car. There were also 23 collisions where the front of a medium sized car hit the side of a small car. Some impact combinations were more frequent than others.

The cell with the largest number of cases corresponds to the front of a large car impacting the side of a small car (65 cases). There were only a handful of fatal collisions where a 4WD was hit on the side by the front of another passenger vehicle. The relative number of crashes in each cell reflects many factors including injury risk, crash risk and traffic density. The small number of 4WD side impacts probably reflects that side impacts on a 4WD are unlikely to be fatal unless the striking vehicle is larger than a passenger vehicle (ie a truck or bus). This type of crash has not been considered in this analysis.

Table 5a. No. of front into side fatal collisions between passenger vehicles of various sizes, Australia 1988, 1990, 1992, 1994

	Size of striking vehicle (frontal impact)				Total
	Small	Medium	Large	4WD	crashes
Size of struck vehicle (side impact)					
Small	**33**	23	65	27	148
Medium	14	**14**	38	15	81
Large	27	15	**58**	8	108
4WD	2	0	2	**1**	5
Total crashes	76	52	163	51	342

Source: FORS Fatality Files 1988, 1990, 1992 and 1994
Shaded cells represent impacts where the struck vehicle is smaller than the striking vehicle.
Bolded figures represent impacts between vehicles of the same size class.

The corresponding mortality ratios for the combinations are given in Table 5b and Figure 2. As for the overall result, the ratios for struck vs striking are generally greater than one, indicating greater risk in the vehicle struck on the side. The only ratios that are less than one are for crash combinations with small numbers of crashes. Although results for side impacts are less consistent than those for frontal crashes, it does appear that the size of both the struck and the striking vehicle are important. As the size of the struck vehicle increases, the mortality ratio tends to decrease. Similarly, as the size of the striking vehicle increases, the mortality ratio increases.

4WD vehicles again appear to generate extreme results. There were 50 fatal crashes where a 4WD struck a car in the side. This resulted in no deaths in the 4WD vehicles (out of 94 occupants) and 66 occupant deaths (out of 110 occupants) in the cars.

An apparent anomaly relates to large cars striking small and medium cars. The DMR for a large car into a small car (22.5) is nearly equivalent to that for large car into medium car (22.0). The all occupant adjusted mortality rate is much higher for large into medium than large into small.

Table 5b. Relative fatal injury risk in front into side collisions between passenger vehicles of various sizes estimated by driver mortality ratios (DMR) and occupant mortality ratios with and without adjustment for number of occupants (OMR_{adj} and OMR)

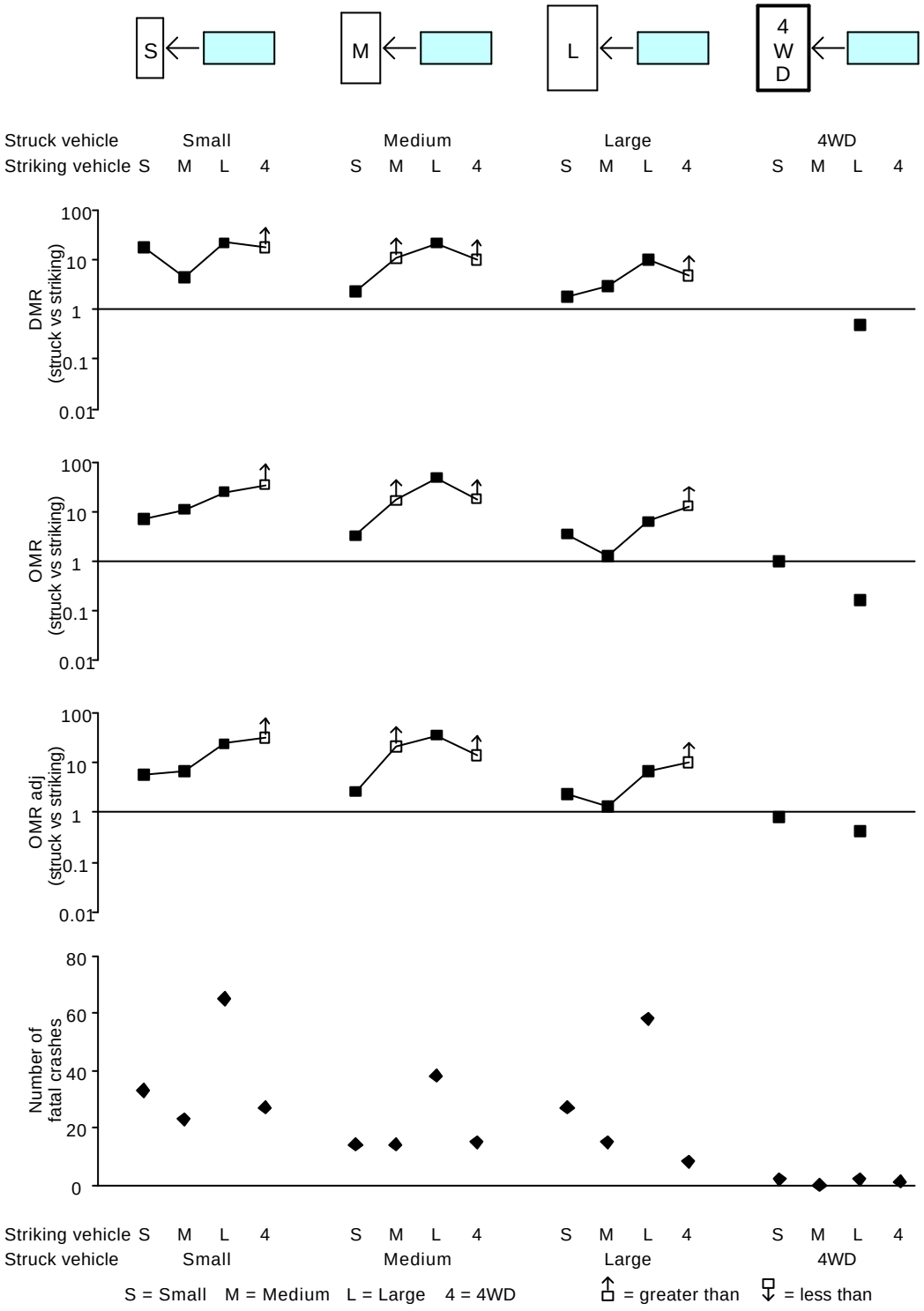
DMR (struck vs striking)	Size of striking vehicle (frontal impact)				Total
	Small	Medium	Large	4WD	
Size of struck vehicle(side impact)					
Small	**18.0**	4.5	22.5	>18.0	18.0
Medium	2.3	**>11.0**	22.0	>10.0	12.5
Large	1.8	3.0	**10.0**	>5.0	5.0
4WD	-	-	0.5	-	0.5
Total	3.8	6.5	12.3	>33.0	9.1

OMR (struck vs striking)	Size of striking vehicle (frontal impact)				Total
	Small	Medium	Large	4WD	
Size of struck vehicle(side impact)					
Small	**7.0**	11.0	25.0	>35.0	16.7
Medium	3.3	**>17.0**	48.0	>18.0	19.2
Large	3.5	1.3	**6.3**	>13.0	4.1
4WD	1.0	-	0.2	**0.0**	0.3
Total	4.3	4.1	9.4	66.0	7.4

OMR_{adj} (struck vs striking)	Size of striking vehicle (frontal impact)				Total
	Small	Medium	Large	4WD	
Size of struck vehicle(side impact)					
Small	**5.9**	7.0	24.6	>31.8	14.6
Medium	2.6	**>21.1**	36.4	>14.4	16.2
Large	2.4	1.4	**6.7**	>10.5	3.8
4WD	0.8	-	0.4	**0.0**	0.5
Total	3.3	3.6	9.1	>60.1	6.7

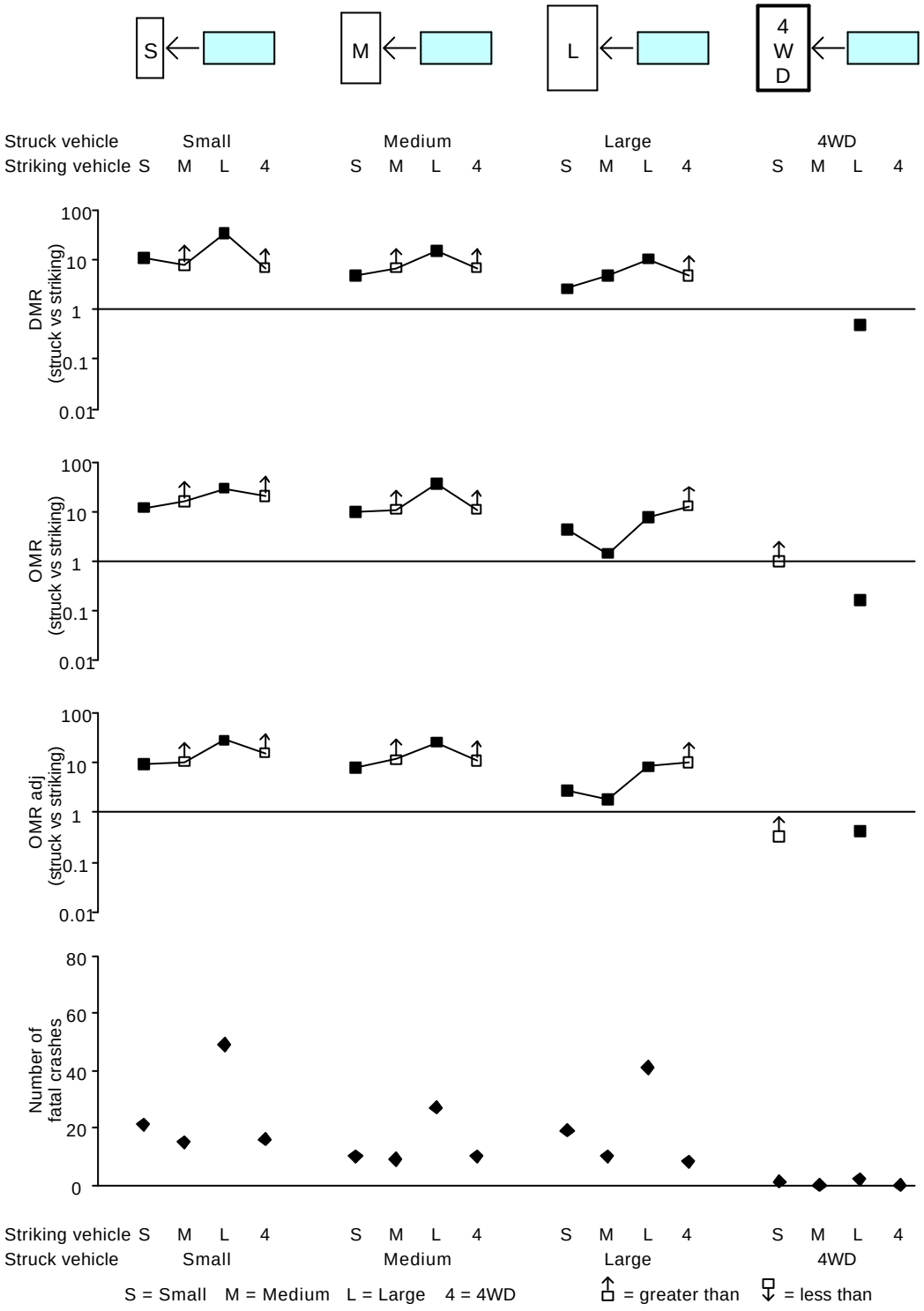
Source: FORS Fatality Files 1988, 1990, 1992 and 1994
Shaded cells represent impacts where the struck vehicle is smaller than the striking vehicle.
Bolded figures represent impacts between vehicles of the same size class.
DMR = #drivers killed in struck vehicles/#drivers killed in striking vehicles
OMR = #occupants killed in struck vehicles/#occupants killed in striking vehicles
OMR_{adj}= (#occupants killed/#occupants in struck vehicles)/(#occupants killed/#occupants in striking vehicles)
Total = Small, medium or large car or 4WD.
- indicates no crashes

Figure 2. Relative fatal injury risk in front into side collisions between passenger vehicles according to vehicle size estimated by driver mortality ratios (DMR) and occupant mortality ratios with and without adjustment for number of occupants (OMR_{adj} and OMR)



Source: FORS Fatality Files 1988, 1990, 1992 and 1994

Figure 3. Relative fatal injury risk in front into side collisions between passenger vehicles according to vehicle size estimated by driver mortality ratios (DMR) and occupant mortality ratios with and without adjustment for number of occupants (OMR_{adj} and OMR), with the definition of side impact restricted to cabin impacts only (Appendix B)



Source: FORS Fatality Files 1988, 1990, 1992 and 1994

Another anomaly relates to small cars into small cars. The DMR is high (18.0). This is similar to the DMR for large cars into small cars (22.5) and much higher than for medium cars into small cars (4.5). These differences are not evident, however, if all occupant deaths are taken into account.

Most of these inconsistencies probably relate to the very small number of deaths in the striking car. The observed mortality ratio is highly sensitive to small changes in these numbers.

Further details of total fatality and occupant counts for each crash combination are in Appendix C (Table C2). The analysis was repeated restricting the side impacts to those impacting within the cabin area (Appendix C Table C3 and Figure 3). This decreased the number of eligible crashes to 238, but similar general patterns were observed.

4 DISCUSSION

Passenger vehicle occupant deaths make up 59% of the national road toll. This corresponds to approximately 1000 fatalities in Australia, annually. The results suggest that occupant protection against a side impact (from another passenger vehicle or narrow object) is as important as frontal protection. The results also suggest that impacts with narrow objects, such as trees and poles, while not resulting in quite as many deaths as collisions between passenger vehicles, are nevertheless substantial, accounting for 21% of all passenger vehicle occupant deaths.

The results suggest that drivers and occupants in smaller vehicles are more likely to be killed in both frontal and side impact collisions with larger passenger vehicles. These results for fatal crashes are similar to those reported by Evans (1991), Gabler & Hollowell (1998), and the Insurance Institute for Highway Safety (1998). The pattern of increasing driver mortality ratios with increasing vehicle size disparity was also observed in the corresponding driver injury ratios reported for casualty crashes by Les et al (1999). However, the magnitude of the mortality ratios was considerably larger than the injury ratios. This reflects that differentials in occupant protection become increasingly important in crash situations that are severe enough to cause fatal injury (ie high speed collisions).

The role of vehicle size in fatal and injury crashes is especially relevant to Australia where sales of small and large cars and 4WD vehicles are increasing, while sales of medium size vehicles are declining. If this continues in the long term, it will promote a vehicle fleet composition with greater size variance and therefore greater risk divergence than in the current fleet.

The study has limitations predominantly in relation to other factors that have not been controlled. While mortality ratios have been adjusted by the number of occupants where relevant, they have not been adjusted for other significant features such as:

- age and sex of occupants/driver
- occupant seating position (except for drivers)
- restraint use
- specific point of impact (eg side impact at front wheel, side impact at driver's door etc, and also driver side/passenger side)
- impact speed.

While it may be the case that some of these variables are randomly distributed across vehicle classes, it may be that others are not. The current study did not (and could not) distinguish between the influence of vehicle mass, stiffness and geometric design on vehicle compatibility. It is intended to conduct further analysis to establish the relevance of these and other variables to the results reported herein.

FORS is conducting a side impact crash test series to examine the effects on injury outcome of the parameters of vehicle mass, stiffness, and geometric design, and impact speed. That research should assist in the further analysis of real world crash data.

REFERENCES

Evans L (1991) Traffic Safety and the Driver. Van Nostrand Reinhold, New York

Gabler H & Hollowell WT (1998) NHTSA's Vehicle Aggressivity and Compatibility Research Program, 16th International Conference on the Enhanced Safety of Vehicles 1998, Paper No. 98-S3-O-01.

Les M, Fildes B, Seyer K & McFadden M. (1999) Vehicle Compatibility: Analysis of real-world non-fatal casualty crashes. Federal Office of Road safety, in press

The Federal Chamber of Automotive Industries (1998) 1997 Black White Data Book, Glass's Guide, Melbourne

The Federal Office of Road Safety (1998) Road Fatalities Australia 1997 Statistical Summary, Canberra

Insurance Institute for Highway Safety (1998) Status Report Vol 33 No. 1 February 14 1998

Mizuno K & Kajzer J (1998) The compatibility of mini cars in traffic accidents, 16th International Conference on the Enhanced Safety of Vehicles 1998, , Paper No. 98-S3-O-08.

Appendix A. Passenger vehicle size classification

SMALL CARS		
Make	**Model**	**Year**
Daihatsu	Applause	89-96
Daihatsu	Charade	82-96
Daihatsu	Handivan	82-90
Ford	Festiva WA	91-93
Ford	Festiva WB	94-96
Ford	Laser KA-KE	82-89
Ford	Laser KF/KH	91-94
Ford	Meteor KA-KE	82-89
Holden	Astra	84-92
Holden	Barina	85-93
Holden	Gemini	82-84
Holden	Gemini RB	86-87
Holden	Nova	89-96
Honda	City	83-86
Honda	Civic	82-95
Hyundai	Excel	82-96
Hyundai	Lantra	91-95
Mazda	121	87-96
Mazda	323	82-94
Mitsubishi	Colt	82-88
Mitsubishi	Cordia	82-89
Mitsubishi	Lancer CA/CB	88-92
Mitsubishi	Lancer CC	95-96
Nissan	Pulsar	84-95
Nissan	Vector	84-92
Rover	Quintet	82-86
Subaru	Sherpa/Fiori	82-92
Suzuki	Hatch	82-85
Suzuki	Swift	85-94
Toyota	Corolla	82-96
Toyota	Tercel	83-88

MEDIUM CARS		
Make	**Model**	**Year**
Ford	Corsair	89-92
Ford	Telstar	83-96
Holden	Apollo JK/JL	89-92
Holden	Camira	82-89
Mazda	626	83-96
Mazda	MX6	83-96
Mitsubishi	Galant	89-96
Mitsubishi	Nimbus	84-91
Mitsubishi	Scorpion	82-86
Mitsubishi	Sigma	82-86
Nissan	Bluebird	82-86
Nissan	Gazelle	84-88
Nissan	Pintara	82-86

MEDIUM CARS, continued		
Make	**Model**	**Year**
Nissan	Pintara	86-92
Nissan	Prairie	84-86
Nissan	Stanza	82-83
Peugeot	505	82-93
Subaru	1800/Leone	82-95
Subaru	Liberty	89-94
Toyota	Camry	83-92
Toyota	Corona	82-87

LARGE CARS		
Make	**Model**	**Year**
Ford	Falcon EA,EB Series I	88-92
Ford	Falcon EB Series II,ED	92-94
Ford	Falcon EF	94-96
Ford	Falcon XD-XF	82-88
Holden	Apollo JM/JP	93-96
Holden	Commodore VB-VL	82-88
Holden	Commodore VN/VP	89-93
Holden	Commodore VR/VS	93-96
Hyundai	Sonata	89-96
Mitsubishi	Magna TM-TP	85-90
Mitsubishi	Magna TR/TS	91-96
Mitsubishi	Verada KR/KS	91-96
Nissan	Skyline	82-90
Toyota	Camry	93-96
Toyota	Lexcen	89-96

4WD VEHICLES		
Make	**Model**	**Year**
Daihatsu	Feroza	89-96
Daihatsu	Rocky F70/75/80	84-96
Ford	Maverick	88-96
Holden	Drover	85-87
Holden	Jackaroo	84-96
Mitsubishi	Pajero	82-90
Nissan	Patrol	82-87
Nissan	Patrol	88-96
Range Rover	Range Rover	82-96
Suzuki	Sierra	82-96
Suzuki	Vitara	88-96
Toyota	4Runner	82-96
Toyota	Hilux	82-96
Toyota	Landcruiser	82-96

Reference: Federal Chamber of Automotive Industries (1997)

Continued next page

Additional classifications for vehicles not in reference list, but in the Fatality File

(generally early models)

SMALL CARS		
Make	**Model**	**Year**
Austin		
Alfa Romero		
Audi		
Datsun	EXA	
Datsun	NX/NX coupe	
Datsun	Sunny	
Datsun	120Y	
Datsun	1600	
Datsun	180B	
Datsun	200B	
Datsun	240	
Datsun	260	
Datsun	2802X	
Fiat		
Ford	Capri	
Ford	Cortina	<1975
Ford	Escort	
Hillman		
Holden	Torana	<1973
Honda	Prelude	<1986
Hyundai		
Lancier		
Leyland		
Mazda	Capella	
Mazda	RX2	
Mazda	RX3	
Mazda	RX7	
Mazda	MX5	
MG		
Morris		
Porsche		
Renault		
Saab		<1977
Subaru		
Toyota	Celica	
Toyota	Seca	
Toyota	Sprinter	
Toyota	T18	
Triumph		
Volkswagon		

MEDIUM CARS		
Make	**Model**	**Year**
BMW		
Ford	Cortina	1975+
Holden	Sunbird	
Holden	Torana	1973+
Honda	Accord	
Honda	Prelude	1986+
Mazda	RX4	
Mazda	929	<1984
Mercedes Benz		
Mitsubishi	Centura	
Mitsubishi	Starion	
Saab		1985+
Toyota	Cressida	
Toyota	Supra	
Volvo		

LARGE CARS		
Make	**Model**	**Year**
Bentley		
Citroen		
Chrysler	Charger	
Chrysler	Regal	
Chrysler	Valiant	
Ford	Belmont	
Ford	Fairlane	
Ford	Fairmont	
Ford	Mustang	
Holden	Calais	
Holden	Caprice	
Holden	Kingswood	
Holden	LTD	
Holden	Monaro	
Holden	Premier	
Holden	Statesman	
Jaguar		
Mazda	929	1987+
Mitsubishi	Pacer/hemi	
Nissan	Maxima	
Rambler		
Toyota	Crown	

4WD VEHICLES		
Make	**Model**	**Year**
Toyota	Sahara	

Appendix B. Impact location

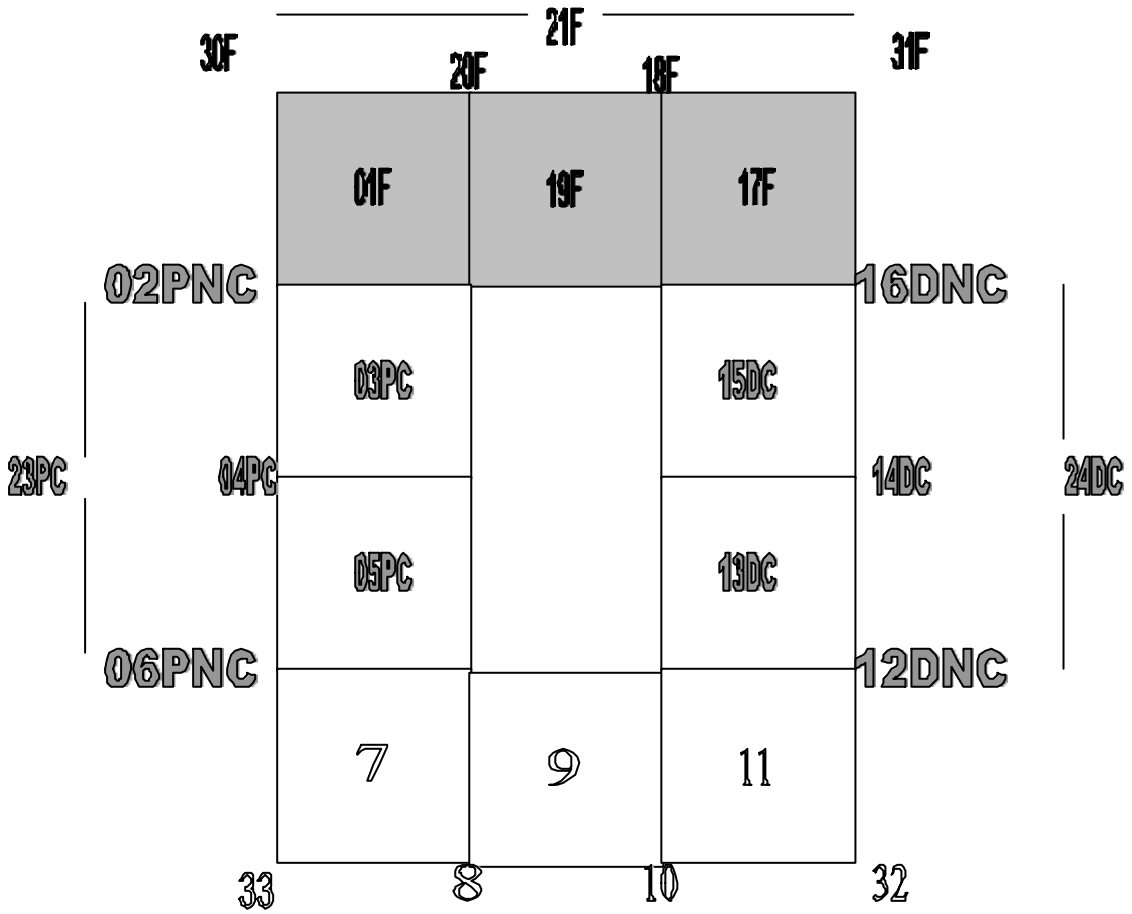
Impacts were classified according to the point of primary impact coded in the Fatality File (PIMP). This is the location of the impact considered to have caused the fatality. Only frontal and side impacts were included in the analysis.

Frontal impacts included all codes corresponding to the front of the vehicle (labelled F on the diagram below).

Side impacts included impacts to the right (driver's side) and left (passenger's side) and were subdivided into cabin and non-cabin impacts as illustrated below. Unspecified left and right side impacts were included as non-cabin impacts.

PNC = Passenger's side, non-cabin
PC = Passenger's side, cabin
DNC = Driver's side, non-cabin
DC = Driver's side, cabin.

Front of vehicle



APPENDIX C. Fatality and occupant counts in frontal and side impacts

Table C1. Number and ratio of occupant and driver deaths in front to front impacts between small, medium and large cars and 4WD vehicles, Australia 1988, 1990, 1992 and 1994

Subject vehicle					Other vehicle				Mortality ratio (subject vs other)			#Fatal	
Occupants	Occ dths	Drv deaths	Front		Front	Drv deaths	Occ dths	Occupants	DMR	OMR	OMR adj	crashes	
59	25	11	Small	<->	Small	14	17	52	0.8	1.5	1.3	34	
59	30	25	Small	<->	Medium	7	12	61	3.6	2.5	2.6	35	
121	71	50	Small	<->	Large	8	14	120	6.3	5.1	5.0	61	
41	24	17	Small	<->	4WD	1	1	43	17.0	24.0	25.2	21	
61	12	7	Medium	<->	Small	25	30	59	0.3	0.4	0.4	35	*Repeat
17	6	5	Medium	<->	Medium	3	6	18	1.7	1.0	1.1	10	
77	31	23	Medium	<->	Large	10	17	81	2.3	1.8	1.9	39	
23	15	9	Medium	<->	4WD	0	0	21	>9.0	>15.0	>13.7	11	
120	14	8	Large	<->	Small	50	71	121	0.2	0.2	0.2	61	*Repeat
81	17	10	Large	<->	Medium	23	31	77	0.4	0.5	0.5	39	*Repeat
57	22	15	Large	<->	Large	8	13	53	1.9	1.7	1.6	27	
52	25	16	Large	<->	4WD	2	4	40	8.0	6.3	4.8	21	
43	1	1	4WD	<->	Small	17	24	41	0.06	0.04	0.04	21	*Repeat
21	0	0	4WD	<->	Medium	9	15	23	<0.1	<0.1	<0.1	11	*Repeat
40	4	2	4WD	<->	Large	16	25	52	0.1	0.2	0.2	21	*Repeat
4	1	1	4WD	<->	4WD	1	1	4	1.0	1.0	1.0	1	
510	250	172	Total	<->	Total	54	85	493	3.2	2.9	2.8	260	
373	196	140	Total excluding same size			28	48	366	5.0	4.1	4.0	188	
116	64	42	Car	<->	4WD	3	5	104	14.0	12.8	11.5	53	
280	150	103	Small	<->	Total	30	44	276	3.4	3.4	3.4	151	
178	64	44	Medium	<->	Total	38	53	179	1.2	1.2	1.2	95	
310	78	49	Large	<->	Total	83	119	291	0.6	0.7	0.6	148	
108	6	4	4WD	<->	Total	43	65	120	0.1	0.1	0.1	54	
221	125	92	Small	<->	>Small	16	27	224	5.8	4.6	4.7	117	
100	46	32	Medium	<->	>Medium	10	17	102	3.2	2.7	2.8	50	
52	25	16	Large	<->	4WD	2	4	40	8.0	6.3	4.8	21	

Total = Small or medium or large or 4WD; Car = Small or medium or large; >Small = Medium or Large or 4WD; >Medium = Large or 4WD

*Repeat indicates where data is a repeat from higher up the table, ie numbers for small<->medium crashes listed under both small subject vehicle & medium subject vehicle

>x Indicates that mortality ratio MR>x; used where no deaths in the other vehicle. x = MR assuming that 1 death in other vehicle.

<x Indicates that mortality ratio MR<x; used where no deaths in the subject vehicle. x = MR assuming that 1 death in the subject vehicle.

Table C2. Number and ratio of occupant and driver deaths in front into side impacts between small, medium and large cars and 4WD vehicles, Australia 1988, 1990, 1992 and 1994

Struck vehicle (hit on the side)				by	Striking vehicle (hit in the front)				Mortality ratio (struck vs striking)			#Fatal
Occupants	Occ dths	Drv deaths	Side	<-	Front	Drv deaths	Occ dths	Occupants	DMR	OMR	OMR adj	crashes
66	35	18	Small	<-	Small	1	5	56	18.0	7.0	5.9	33
55	22	9	Small	<-	Medium	2	2	35	4.5	11.0	7.0	23
115	75	45	Small	<-	Large	2	3	113	22.5	25.0	24.6	65
54	35	18	Small	<-	4WD	0	0	49	>18.0	>35.0	>31.8	27
26	13	7	Medium	<-	Small	3	4	21	2.3	3.3	2.6	14
25	17	11	Medium	<-	Medium	0	0	31	>11.0	>17.0	>21.1	14
87	48	22	Medium	<-	Large	1	1	66	22.0	48.0	36.4	38
35	18	10	Medium	<-	4WD	0	0	28	>10.0	>18.0	>14.4	15
69	28	9	Large	<-	Small	5	8	47	1.8	3.5	2.4	27
30	14	6	Large	<-	Medium	2	11	32	3.0	1.3	1.4	15
121	63	30	Large	<-	Large	3	10	129	10.0	6.3	6.7	58
21	13	5	Large	<-	4WD	0	0	17	>5.0	>13.0	>10.5	8
5	1	0	4WD	<-	Small	0	1	4	-	1.0	0.8	2
0	0	0	4WD	<-	Medium	0	0	0	-	-	-	0
4	1	1	4WD	<-	Large	2	6	10	0.5	0.2	0.4	2
1	0	0	4WD	<-	4WD	0	1	7	-	0.0	0.0	1
714	383	191	Total	<-	Total	21	52	645	9.1	7.4	6.7	342
594	315	157	Car	<-	Car	19	44	530	8.3	7.2	6.4	287
110	66	33	Car	<-	4WD	0	0	94	>33.0	>66.0	>56.4	50
166	77	34	Total	<-	Small	9	18	128	3.8	4.3	3.3	76
110	53	26	Total	<-	Medium	4	13	98	6.5	4.1	3.6	52
327	187	98	Total	<-	Large	8	20	318	12.3	9.4	9.1	163
111	66	33	Total	<-	4WD	0	1	101	>33.0	66.0	>60.1	51
290	167	90	Small	<-	Total	5	10	253	18.0	16.7	14.6	148
173	96	50	Medium	<-	Total	4	5	146	12.5	19.2	16.2	81
241	118	50	Large	<-	Total	10	29	225	5.0	4.1	3.8	108
10	2	1	4WD	<-	Total	2	8	21	0.5	0.3	0.5	5

Total = Small or medium or large or 4WD: Car = Small or medium or large
>x Indicates that mortality ratio MR>x: used where no deaths in the other vehicle. x = MR assuming that 1 death in other vehicle.

Table C3. Number and ratio of occupant and driver deaths in front into side impacts between small, medium and large cars and 4WD vehicles (Side impacts restricted to cabin impacts – see Appendix B), Australia 1988, 1990, 1992 and 1994

Struck vehicle (hit on the side - cabin only)				by	Striking vehicle (hit in the front)				Mortality ratio (struck vs striking)			#Fatal
Occupants	Occ dths	Drv deaths	Side	<-	Front	Drv deaths	Occ dths	Occupants	DMR	OMR	OMR adj	Crashes
40	24	11	Small	<-	Small	1	2	31	11.0	12.0	9.3	21
36	16	8	Small	<-	Medium	0	0	24	>8.0	>16.0	>10.7	15
90	59	35	Small	<-	Large	1	2	89	35.0	29.5	29.2	49
36	20	7	Small	<-	4WD	0	0	29	>7.0	>20.0	>16.1	16
19	10	5	Medium	<-	Small	1	1	15	5.0	10.0	7.9	10
16	11	7	Medium	<-	Medium	0	0	17	>7.0	>11.0	>11.7	9
63	36	15	Medium	<-	Large	1	1	46	15.0	36.0	26.3	27
23	11	7	Medium	<-	4WD	0	0	23	>7.0	>11.0	>11.0	10
50	22	8	Large	<-	Small	3	5	32	2.7	4.4	2.8	19
17	10	5	Large	<-	Medium	1	7	22	5.0	1.4	1.8	10
86	46	21	Large	<-	Large	2	6	96	10.5	7.7	8.6	41
21	13	5	Large	<-	4WD	0	0	17	>5.0	>13.0	>10.5	8
3	1	0	4WD	<-	Small	0	0	1	-	>1.0	>0.3	1
0	0	0	4WD	<-	Medium	0	0	0	-	-	-	0
4	1	1	4WD	<-	Large	2	6	10	0.5	0.2	0.4	2
0	0	0	4WD	<-	4WD	0	0	0	-	-	-	0
504	280	135	Total	<-	Total	12	30	452	11.3	9.3	8.4	238
417	234	115	Car	<-	Car	10	24	372	11.5	9.8	8.7	201
80	44	19	Car	<-	4WD	0	0	69	>19.0	>44.0	>38.0	34
112	57	24	Total	<-	Small	5	8	79	4.8	7.1	5.0	51
69	37	20	Total	<-	Medium	1	7	63	20.0	5.3	4.8	34
243	142	72	Total	<-	Large	6	15	241	12.0	9.5	9.4	119
80	44	19	Total	<-	4WD	0	0	69	>19.0	>44.0	38.0	34
202	119	61	Small	<-	Total	2	4	173	30.5	29.8	25.5	101
121	68	34	Medium	<-	Total	2	2	101	17.0	34.0	28.4	56
174	91	39	Large	<-	Total	6	18	167	6.5	5.1	4.9	78
7	2	1	4WD	<-	Total	2	6	11	0.5	0.3	0.5	3

Total = Small or medium or large or 4WD; Car = Small or medium or large

>x Indicates that mortality ratio MR>x; used where no deaths in the other vehicle. x = MR assuming that 1 death in other vehicle.