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Rear end crashes

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ABSTRACT

Due to the common occurrence of rear end collisions in South Australia, and the costliness of Compulsory Third Party (CTP) claims associated with them, a study was undertaken into the nature of, and possible countermeasures for, rear end collisions. This study included an analysis of five years of police-reported crash data, an analysis of a sample of rear end crashes investigated as part of the CASR metropolitan in-depth crash study, and a literature review concerned with countermeasures for rear end crashes. The most common factors contributing to these types of crashes are the lack of protection for right turning vehicles and the inadequate allocation of attention by drivers to the driving task. Countermeasures are available for both of these contributing factors. Providing greater protection for right turning vehicles requires road-based countermeasures, while the most promising countermeasure for inadequate allocation of attention is the installation in vehicles of collision avoidance systems. However, the latter countermeasure will only be available after further testing and refinement of current prototype systems.

KEYWORDS

Rear end collision, Accident investigation, Accident countermeasure, Data analysis, Literature review

Summary

Due to the common occurrence of rear end collisions in South Australia, and the costliness of Compulsory Third Party (CTP) claims associated with them, a study was undertaken into the nature of, and possible countermeasures for, rear end collisions. This study included an analysis of five years of police-reported crash data, an analysis of a sample of rear end crashes investigated as part of the CASR metropolitan in-depth crash study, and a literature review concerned with countermeasures for rear end crashes.

The results of the analysis of the mass data on police-reported crashes and the in-depth crash investigation were consistent, with most rear end crashes occurring on straight, level roads and in clear weather conditions. Both analyses also revealed that drivers of striking vehicles were more likely to be young and male than drivers of the vehicles they struck. This is consistent with notions that young, male drivers represent a problematic group of drivers who are often crash-involved and also tend to be responsible for their crashes. Rear end crashes, in this respect, are typical of crashes in general. Injuries resulting from rear end crashes tended to be of low severity, and the in-depth study revealed that occupants of struck vehicles were more likely to require hospital treatment than occupants of striking vehicles.

Factors that increase the likelihood of the occurrence of rear end collisions include higher traffic density (i.e. peak hour traffic; arterial roads), the presence of an intersection, and the presence of a right turning vehicle. These factors are related to rear end crashes because they increase the likelihood of conflict with slowing or stationary vehicles on the road.

There are a number of countermeasures to reduce rear end crashes involving stationary, right turning vehicles. Where intersections feature a high frequency of rear end collisions with right turning vehicles, possible countermeasures include: relocation of the right turn to a different intersection, provision of a right turn only lane, increasing the storage capacity of the right turn lane so that turning vehicles are not forced to queue in adjacent through lanes, and increasing the duration of right turn arrows. The sample of rear end crashes investigated in the in-depth study included cases in which a vehicle was waiting to turn right from an arterial road without the benefit of a designated right turn only lane, and also included a case in which the capacity of the right turn lane was insufficient to cope with the number of vehicles waiting to turn right, resulting in a vehicle protruding into the through lane and being struck in the rear. There were also a number of crashes in which a vehicle was struck when waiting to turn right from a single lane road that did not allow through traffic to pass on the left. For the latter crashes, available engineering solutions are likely to be prohibitively expensive, unless traffic volumes satisfy the requirements for a major upgrade of the road, as was the case for the road in one of the crashes investigated. Such crashes may need to be addressed using countermeasures for inadequate allocation of attention (see below).

Countermeasures are also available for left turning traffic at intersections. Slip lanes that make turning simpler can be introduced, enabling left turning traffic to turn into the adjoining road prior to merging with traffic, or a larger angle between the left turn lane and adjoining road can be used, enabling better visibility of traffic to aid the determination of gap acceptance. There was one crash in the in-depth study involving a left turning vehicle being struck from behind. The striking driver moved in response to a gap in the traffic on the adjoining road in anticipation of the struck vehicle turning. If the left turn had been simpler, the struck vehicle may have been able to turn at this point rather than remaining stationary, although inadequate allocation of attention on the part of the striking driver was still the prime determining factor of the crash.

Another factor that can increase the likelihood of rear end collisions is a parked vehicle by the side of the road. Clearways and parking restrictions on the approach to intersections are useful because they enhance the visibility of the intersection and other traffic, and reduce obstacles in the vicinity of the intersection that could cause vehicles to stop. The in-depth study included three cases in which legally parked vehicles may have contributed to the

occurrence of a rear end collision. It is also important to note that both the Traffic Accident Reporting Systems (TARS) analysis and the in-depth study analysis excluded cases where the struck vehicle was parked (as such crashes are often classified as 'hit parked vehicle' rather than 'rear end collision'). In the in-depth study, seven of the original sample of 47 cases classified as rear end crashes involved collisions into the rear of parked vehicles.

Relatively few rear end collisions in the in-depth study were the result of the restriction of driver vision caused by curved roads. This is consistent with the small percentage of such crashes that occur on curved roads in South Australia, as seen in the analysis of data on police-reported crashes. This low frequency of rear end crashes on curved roads is likely to be due to relative paucity of curved roads in metropolitan Adelaide. Nonetheless, the literature suggests that where intersections are present shortly after a curve in the road, it would be useful for drivers to be warned by appropriate signs of the possibility of queued stationary traffic following the curve.

Also, relatively few rear end crashes in the in-depth study were associated with wet weather, as was the case with the police-reported crashes included in the TARS analysis, This would suggest that relatively few of the crashes would have been avoided, or their severity reduced, by skid resistance treatment of the road surface. Skid resistance treatments, however, may still prove cost-beneficial in South Australia if applied to roads with high crash rates, especially if such roads have a high ratio of wet to dry weather crashes or are characterised by a marked down slope.

Turning to driver-related factors, inadequate allocation of attention was found in the in-depth crash study to be a frequent contributor to rear end crash causation, and may have been underestimated in the results, given that interviews in which attentional issues were explored were not possible with all crash participants. Inadequate allocation of attention could be divided into four different types: cases in which drivers were not sufficiently focused on the driving task; cases in which drivers were distracted from the driving task by objects or events either in or outside the vehicle; cases in which the drivers were unable to adequately divide their attention between two or more driving-related tasks; and cases in which drivers were unable to adequately allocate their attention to appropriate aspects of the road and traffic environment when changing lanes.

In order to combat the inadequate allocation of attention of drivers, the necessary countermeasure would be the installation in vehicles of collision avoidance systems. Such systems typically combine adaptive cruise control, which slows the vehicle automatically in response to the presence of slower vehicles ahead, and devices that actively alert the driver to the need to apply heavier braking to avoid a collision. Early studies of prototype collision avoidance systems have revealed that they are capable of providing useful early warnings to drivers of the need to take evasive action to avoid collisions. However, it is necessary to examine the way drivers interact with them in real-world settings before being certain that they can provide cost-effective reductions in levels of crash involvement. Specifically, it needs to be assessed whether drivers begin to disregard the collision warnings after a series of 'nuisance' alarms.

The literature also suggests the advantages of increasing the conspicuity of the rear of vehicles to decrease the likelihood of rear end collisions. Few crashes in the in-depth study were attended at night, and none of those occurring during the day was clearly related to the low conspicuity of the rear of the struck vehicle. Although this may mean that low conspicuity is not a common factor in rear end crashes, there are likely to be some such crashes in which it is. The use of specially designed lights on the rear of vehicles to warn following drivers that they are too close or closing too quickly may prove useful, by both increasing conspicuity and combating the inattention of following drivers, although work on these projects is in the early stages only.

Finally, a number of the rear end collisions investigated in the in-depth study were associated with medical conditions and/or drug use on the part of the driver of the striking vehicle. Although these crashes also involved inadequate allocation of attention to the driving task, it is unclear whether collision avoidance systems would have been sufficient to prevent their occurrence. These cases highlight the importance of the application of medical fitness to drive guidelines (Austroads, 2001) to prevent people driving when their condition is incompatible with the safe operation of a motor vehicle.

In summary, this report has provided a detailed account of the nature of rear end collisions, using both mass data on police-reported crashes and the information collected in in-depth metropolitan crash investigations. The most common factors contributing to these types of crashes are the lack of protection for right turning vehicles from following traffic and the inadequate allocation of attention by drivers to the driving task. Countermeasures are available for both of these contributing factors. Also, although not directly addressed in this report, it needs to be borne in mind that countermeasures that reduce traffic congestion would also provide major reductions in rear end collisions.

Contents

1 Introduction

Rear end crashes are one of the most common crash types in South Australia and are known to generate a large number of whiplash injuries and, as a consequence, costly Compulsory Third Party (CTP) claims. For these reasons, there is value in understanding more about the characteristics of rear end crashes in South Australia. To this end, CASR have extracted data from the Traffic Accident Reporting System (TARS), consisting of police reports on crashes, and data files compiled from our in-depth investigation of metropolitan road crashes in Adelaide. TARS and in-depth crash investigation data provide complementary information regarding the nature of rear end crashes and are analysed in Sections 2 and 3, respectively.

In addition, literature pertaining to rear end crashes has been reviewed, in order to identify means by which the frequency of rear end crashes can be reduced. Road-based and vehicle-based countermeasures for rear end crashes are discussed in Section 4.

2 TARS analysis

This section analyses South Australian police-reported rear end crash data in an attempt to characterise this type of crash. Five years of data were used and analyses focused on the circumstances of the crash and characteristics of the drivers involved.

2.1 Data source

The Traffic Accident Reporting System (TARS) database is maintained by the South Australian Department for Transport, Energy and Infrastructure (DTEI) and is based on crashes reported to the police. It represents the best available data on the occurrence of road crashes in South Australia, having, at the time of writing, complete data for crashes from 1981 to June 2004.

For the current analysis, casualty crashes for the years 1998 to 2002 inclusive, as recorded in TARS, were analysed as a group. These years were chosen because the property damage limit for property damage only crashes was raised in 2003 to $3,000 (from $1,000 as specified for the years 1998-2002). Note that the TARS data as supplied to the Centre in July 2005 were used. TARS is being constantly updated so re-running the analyses presented here on a different version of the TARS data may produce slightly different results. The total number of crashes for these five years was 203,140. Of these, 67,693 (33%) were classified as rear end crashes.

The first part of the analysis (Section 2.2.1) is concerned with all crash types, comparing those, which were classified as rear end crashes with all other crashes. This section excludes cases featuring a number of ‘unit’ types (pedal cycle, railway vehicle, tram, small wheel vehicle, tree, traffic signal pole, bridge, guard rail, sign post, Stobie pole, other pole, pedestrian in car park, pedestrian on road, ridden animal, animal drawn vehicle, domestic animal - not ridden, wild animal, other fixed obstruction, other). Furthermore, crashes classified as ‘rear end collisions’ but which featured less than two motor vehicles were also excluded. Of the original 67,693 crashes, 422 were thus excluded (216 featuring excluded unit types and 206 featuring less than two vehicles). Finally, crashes were also excluded if they involved parked vehicles, vehicles exiting a parking space, or vehicles that were reversing. This gave a total number of rear end crashes in the analysis of 61,024, and a comparison group of 142,116 ‘other’ crashes.

The second section (Section 2.2.2) provides an analysis of the rear end crash sample only and involves a comparison of the vehicles and drivers responsible for the crash with those not responsible. Efforts were made to only include cases in this sample for which the responsible vehicle was the ‘striking’ (i.e. rear) vehicle, in order to be able to compare the striking vehicle with the ‘struck’ (i.e. front) vehicle. The method for excluding other cases is provided prior to the results of this analysis in Section 2.2.2.

2.2 Results

2.2.1 Comparing rear end crashes with other crashes

This section provides a comparison of the rear end crashes with other types of crashes, with regard to a number of variables. These crash-related variables are: geographical area, hour of the day, day of the week, road geometry, wetness of the road, presence of rain, lighting conditions, crash injury severity, traffic control, road vertical alignment, and road horizontal alignment. The relationships between these variables and rear end crashes were explored to determine if there were any common characteristics of the sample of rear end crashes that differentiated them from other crash types.

GEOGRAPHICAL AREA

The geographical areas defined in the TARS database are City (inner Adelaide), Metropolitan (rest of Adelaide) and Country (outside Adelaide). The number of rear end and other crashes occurring in these areas are shown in Table 2.1.

Table 2.1
Crash type by geographical area

Geographical area	Rear end crashes	Other crashes	Rear end (%)	Other (%)
Metropolitan	51,085	100,112	83.7	70.4
City	6,412	11,427	10.5	8.1
Country	3,527	30,577	5.8	21.5
Total	61,024	142,116	100.0	100.0

Just over 10 percent of the rear end crashes occurred in the city, 84 percent in the metropolitan area and only six percent in the country. Other crash types were similarly most likely to occur in the metropolitan area but, unlike rear end crashes, other crash types were more likely to occur in country areas than in inner Adelaide. Expressed another way, rear end crashes comprised 36 percent of all city crashes and 34 percent of all metropolitan area crashes but only 10 percent of country crashes. The proportions of all crashes that occurred in the city, metropolitan area and the country were nine percent, 74 percent and 17 percent, respectively.

HOUR OF CRASH

Figure 2.1 allows for a comparison of rear end crashes with other crashes, with reference to when they occurred during the day. It can be seen in Figure 2.1 that rear end crash frequencies followed the pattern of all crashes, except for higher peaks from 8am to 9am and from 3pm to 6pm, and fewer occurring between 7pm and 7am. The peaks therefore occurred at the times of peak traffic volumes.

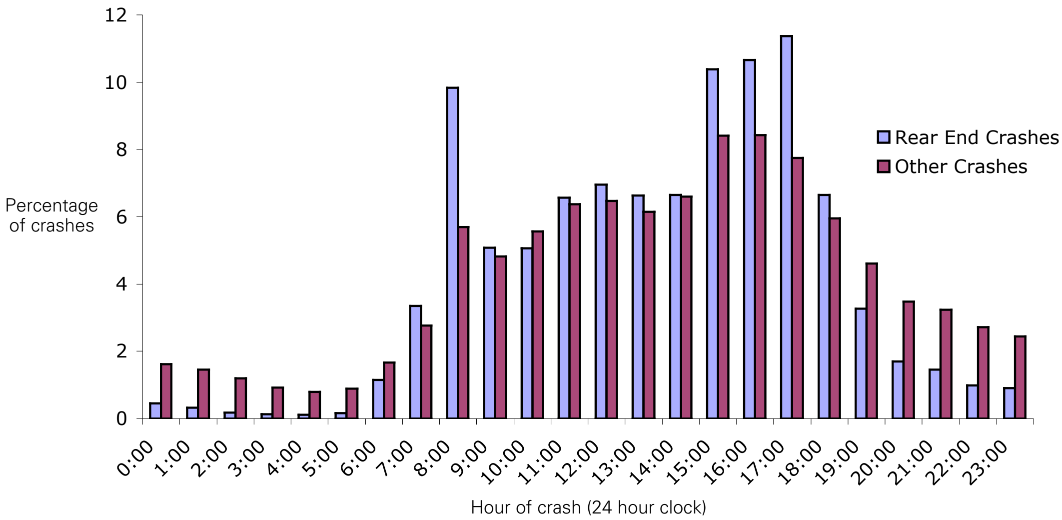

Figure 2.1
Hour of crash for rear end and all other crashes

DAY OF WEEK

Table 2.2 provides details of the day of week on which different crash types occurred. It can be seen that the frequency of rear end crashes was greater during the weekdays, rising steadily from 14 percent of rear end crashes occurring on Mondays to a peak of 18 percent on Fridays. Compared with other crash types, rear end crashes appear to have been under-represented on weekends.

Table 2.2
Crash type by day of week

Day of week	Rear end crashes	Other crashes	Rear end (%)	Other (%)
Monday	8,616	18,778	14.1	13.2
Tuesday	9,365	19,375	15.3	13.6
Wednesday	9,921	20,847	16.3	14.7
Thursday	10,760	22,672	17.6	16.0
Friday	11,051	24,451	18.1	17.2
Saturday	6,884	20,706	11.3	14.6
Sunday	4,427	15,287	7.3	10.8
Total	61,024	142,116	100.0	100.0

ROAD LAYOUT

Table 2.3 shows the number of crashes of different types occurring at sites characterised by different types of road layout. Road layouts classified in the 'Other' category include Y-junctions, pedestrian crossings, freeways, rail crossings, interchanges, on and off ramps, cross overs and one-way roads.

Rear end crashes appear to have been over-represented at, or near, cross roads, and on divided roads. They were correspondingly under-represented on undivided roads.

Table 2.3
Crash type by road layout

Road layout	Rear end crashes	Other crashes	Rear end (%)	Other (%)
Cross road	19,761	25,806	32.4	18.2
Divided road	18,489	22,129	30.3	15.6
T-junction	14,829	28,975	24.3	20.4
Undivided road	4,769	42,398	7.8	29.8
Multiple	1,301	1,817	2.1	1.3
Other	1,875	20,991	3.1	14.8
Total	61,024	142,116	100.0	100.0

ROAD WETNESS

Table 2.4 shows the number of crashes of different types that occurred on wet or dry roads. It appears from the Table that road wetness did not greatly affect the relative frequency of rear end crashes compared with other crash types.

Table 2.4
Crash type by road wetness

Road wetness	Rear end crashes	Other crashes	Rear end (%)	Other (%)
Dry	52,859	124,088	86.6	87.3
Wet	8,165	18,028	13.4	12.7
Total	61,024	142,116	100.0	100.0

PRESENCE OF RAIN

Table 2.5 shows the number of crashes of different types that occurred when it was raining and when it was not. Reflecting the findings for road wetness, the Table below shows that the presence of rain had no significant effect on rear end crash numbers relative to other crash types. There was one crash for which weather conditions were unknown.

Table 2.5
Crash type by presence of rain

Presence of rain	Rear end crashes	Other crashes	Rear end (%)	Other (%)
Not raining	55,720	129,957	91.3	91.4
Raining	5,304	12,158	8.7	8.6
Total	61,024	142,115*	100.0	100.0

* For one 'other' crash, the presence or not of rain was unknown

LIGHTING CONDITIONS

The proportion of crashes of different types that occurred in the three categories of lighting conditions (daylight, night, dawn/dusk) is shown in Table 2.6. It can be seen that rear end crashes were over-represented during daylight hours and under-represented at night.

Table 2.6
Crash type by lighting conditions

Lighting conditions	Rear end crashes	Other crashes	Rear end (%)	Other (%)
Daylight	52,647	105,632	86.3	74.3
Night	6,889	32,648	11.3	22.9
Dawn or dusk	1,488	3,835	2.4	2.7
Total	61,024	142,115*	100.0	100.0

* For one 'other' crash, the lighting conditions were unknown

CRASH INJURY SEVERITY

Crash injury severity is measured by the highest level of injury sustained by any of the crash participants. Table 2.7 shows that rear end crashes tended to result in low injury severity, with an under-representation of crashes requiring hospital treatment or admission of crash participants, and an under-representation of fatal crashes. Also of note was that the percentages of property damage only crashes were about the same for the two groups of crashes.

Table 2.7
Crash type by crash injury severity

Crash injury severity	Rear end crashes	Other crashes	Rear end (%)	Other (%)
Property damage only	50,317	115,352	82.5	81.2
Treated by doctor	7,011	6,378	11.5	4.5
Treated by hospital	3,228	13,977	5.3	9.8
Admitted to hospital	454	5,714	0.7	4.0
Fatal	14	695	0.0	0.5
Total	61,024	142,116	100.0	100.0

TRAFFIC CONTROL

Table 2.8 shows the traffic controls present at the site for the two sets of crashes. The main differences between rear end crashes and other crash types was the under-representation of rear end crashes in situations without any traffic control devices, and the over-representation of rear end crashes at sites controlled by traffic signals.

Table 2.8
Crash type by traffic control

Type of traffic control	Rear end crashes	Other crashes	Rear end (%)	Other (%)
No control	34,050	109,955	55.8	77.4
Traffic signals	22,209	18,003	36.4	12.7
Roundabout	1,677	3,728	2.7	2.7
Stop sign	1,609	4,742	2.6	3.3
Give Way sign	1,257	5,496	2.1	3.9
Rail crossing	156	133	0.3	0.1
Other	66	59	0.1	0.0
Total	61,024	142,116	100.0	100.0

ROAD VERTICAL ALIGNMENT

Table 2.9 shows the vertical alignment of the roads at which the two sets of crashes occurred. It can be seen that rear end crashes were slightly over-represented on level roads and under-represented on slopes, crests and at the bottom of hills.

Table 2.9
Crash type by road vertical alignment

Vertical alignment	Rear end crashes	Other crashes	Rear end (%)	Other (%)
Level	56,457	124,561	92.5	87.6
Slope	3,384	12,608	5.6	8.9
Crest of hill	686	2,787	1.1	2.0
Bottom of hill	429	1,666	0.7	1.2
Unknown	68	494	0.1	0.3
Total	61,024	142,116	100.0	100.0

ROAD HORIZONTAL ALIGNMENT

Table 2.10 shows the horizontal alignment of the roads at which the two sets of crashes occurred. Rear end crashes were over-represented on straight roads, and correspondingly under-represented on curved roads.

Table 2.10
Crash type by road horizontal alignment

Horizontal alignment	Rear end crashes	Other crashes	Rear end (%)	Other (%)
Straight road	58,688	126,872	96.2	89.3
Curved - view open	1,828	9,134	3.0	6.4
Curved - view obscured	487	5,758	0.8	4.1
Unknown	21	352	0.0	0.2
Total	61,024	142,116	100.0	100.0

2.2.2 Rear end crash-involved drivers by crash responsibility

This section focuses only on the sample of rear end crashes, with comparisons made between the striking vehicles and the struck vehicles in cases for which the driver of the striking vehicle was responsible for the crash. The variables included in the analysis consist of vehicle type, driver sex, driver age and licence status. To limit the rear end sample to appropriate rear end cases in which the vehicle driven by the responsible driver was also the striking vehicle, a number of cases had to be excluded.

Table 2.11
Vehicle type by driver responsibility in rear end crashes

Error type	Rear end	Other	Rear end (%)	Other (%)
Inattention	45,011	41,125	73.8	28.9
Follow too closely	14,343	293	23.5	0.2
Change lanes to endanger	756	7,131	1.2	5.0
Overtake without due care	210	3,333	0.3	2.3
Excessive speed	118	1,248	0.2	0.9
DUI	117	1,720	0.2	1.2
Died sick or asleep at wheel	79	1,006	0.1	0.7
Brake failure	69	120	0.1	0.1
Misjudgement	51	3,479	0.1	2.4
Vehicle fault	33	2,112	0.1	1.5
Dangerous driving	16	166	0.0	0.1
Fail to give way	6	25,418	0.0	17.9
Insecure load	4	437	0.0	0.3
Broken windscreen	2	1	0.0	0.0
Disobey - traffic lights	1	3,344	0.0	2.4
Fail to keep left	1	3,710	0.0	2.6
Incorrect turn	1	1,210	0.0	0.9
Disobey - Give Way sign	0	3,389	0.0	2.4
Disobey - police signal	0	3	0.0	0.0
Disobey - railway signal	0	8	0.0	0.0
Disobey - Stop sign	0	2,559	0.0	1.8
Drunken pedestrian	0	194	0.0	0.1
Fail to give way right	0	944	0.0	0.7
Fail to stand	0	9,847	0.0	6.9
Incorrect or no signal	0	145	0.0	0.1
Opening or closing door	0	1,004	0.0	0.7
Reverse without due care*	0	22,027	0.0	15.5
NA	153	5,400	0.3	3.8
Other	48	722	0.1	0.5
None	5	21	0.0	0.0
Total	61,024	142,116	100.0	100.0

* Reverse without due care crashes all classified for analysis as 'Other' type of crash

The total rear end sample that was used in the previous section included 73.8 percent of cases in which the police-designated error was 'inattention' and 23.5 percent of cases in which the error was 'follow too closely' (see Table 2.11). 'Change lanes to endanger' (1.2%) was the next highest category of error. All other errors accounted for less than 1.5 percent of cases. Within the 'change lanes to endanger' error group, the vehicle movements were investigated to determine whether the responsible vehicle was the striking or struck vehicle. For all except one of the cases in which the responsible vehicle error was 'change lanes to endanger', the vehicle's movement was 'swerving'. For cases in which the non-responsible vehicle movement was 'stopped on carriageway', it was assumed that the responsible vehicle was striking. This was checked for approximately 10 percent of these cases and all of the randomly selected cases confirmed this assumption. For the non-responsible vehicle movement of 'straight ahead', half of the checked cases involved the responsible vehicle striking and half being struck but this portion only accounted for 0.75 percent of the total sample and so has not been excluded from the set. For cases in which the non-responsible vehicle movement was also 'swerving', the responsible vehicles were both striking and struck, but again this group was insignificant within the responsible vehicle sample (0.01%) and so these cases were not excluded. For all other cases of 'change lanes to endanger', it was checked that the responsible vehicle was the striking vehicle.

Another error and non-responsible vehicle movement combination for which the responsible vehicle was not always the striking vehicle was the combination of 'fail to give way' as the error and 'straight ahead' as the non-responsible vehicle movement. Although the responsible vehicle in these cases was not always the striking vehicle, these cases were left in the sample, as they comprised less than 0.01 percent of the responsible vehicles.

The cases for which the responsible vehicle error was 'insecure load' involved objects falling from the back of a truck or utility (a bail of hay, a 20 litre metal drum, and a car). In each case, the vehicles following the truck or utility stopped to avoid the item on the road and were struck by vehicles travelling behind them, the drivers of which were unaware of the obstruction. These cases have been excluded.

Finally, to ensure that the striking and struck vehicles could be successfully identified, cases in this section were restricted to those involving only two appropriate units (see Section 2.1 for a list of inappropriate units). In cases in which there were more than two appropriate units, it could not be assumed that the first two units listed in the dataset included the striking vehicle and the vehicle it struck.

The exclusion of the cases as described here resulted in a data set of 57,152 cases. For each of these cases, there was one striking and one struck vehicle. Characteristics of these vehicles and their drivers are compared in this section.

VEHICLE TYPE

Table 2.12 shows the number of different vehicle types involved in rear end crashes, according to whether they were the striking or struck vehicle in the crash. Although there is some evidence of an over-representation of trucks and semi-trailers among the striking vehicles group, the numbers are relatively small.

Table 2.12
Vehicle type by driver responsibility in rear end crashes

Vehicle type	Striking	Struck	Striking (%)	Struck (%)
Car	38,635	41,630	67.6	72.8
Station wagon	7,654	7,109	13.4	12.4
Utility	2,704	2,256	4.7	3.9
Panel van	2,066	1,476	3.6	2.6
Truck	1,026	660	1.8	1.2
Taxi cab	615	660	1.1	1.2
Semi trailer	423	154	0.7	0.3
Motorcycle	314	179	0.5	0.3
Omnibus	195	208	0.3	0.4
Passenger van	21	16	0.0	0.0
Other vehicle	154	99	0.3	0.2
Unknown vehicle	3,345	2,705	5.9	4.7
Total	57,152	57,152	100.0	100.0

DRIVER SEX

Male drivers accounted for 60 percent of the drivers of striking vehicles and 54 percent of the drivers of struck vehicles (see Table 2.13). This shows that males were over-represented in rear end crashes, relative to females, and also shows a trend for males to be more likely to be responsible for their crashes.

Table 2.13
Driver sex by driver responsibility in rear end crashes

Driver sex	Striking	Struck	Striking (%)	Struck (%)
Male	34,501	30,912	60.4	54.1
Female	20,199	24,650	35.3	43.1
Unknown or other	2,452	1,590	4.3	2.8
Total	57,152	57,152	100.0	100.0

DRIVER AGE

Figure 2.2 shows the percentage of drivers in different age groups who were in the striking or struck vehicles in the crash. Young drivers were the most likely to be in the striking vehicles in rear end crashes. The 20 to 24 age group was responsible for the highest percentage of crashes, followed by those aged under 20. Within the under 20 age group, there were 12 drivers under the age of 16 (the minimum age at which to obtain a learner's permit), seven of whom were recorded as being in the striking vehicle in the crash. Middle-aged drivers (aged 35-59) were the least likely to be in the striking vehicle in the rear end crashes in which they were involved.

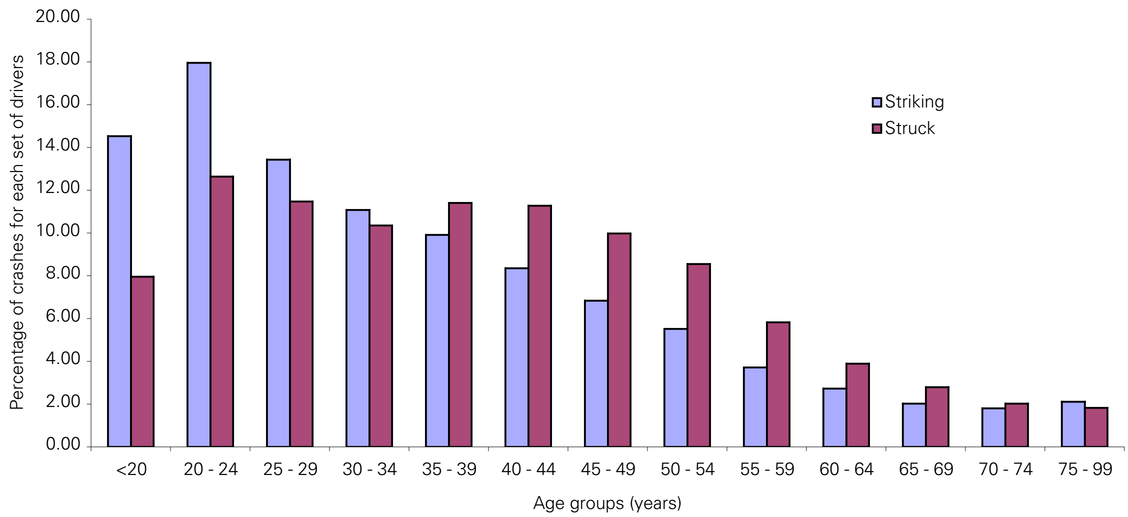

Figure 2.2
Driver responsibility by age for rear end crashes

LICENCE STATUS

Table 2.14 shows the licence status of the drivers involved in rear end crashes, by crash responsibility. It can be seen that drivers with a full licence were under-represented among those who were the striking driver in their crashes, while provisional licence holders were over-represented in the striking driver group.

Table 2.14
Driver licence type by driver responsibility in rear end crashes

Driver licence status	Striking	Struck	Striking (%)	Struck (%)
Full	37,463	45,382	65.5	79.4
Provisional	5,475	3,359	9.6	5.9
Learners	213	199	0.4	0.3
Unlicensed	67	35	0.1	0.1
Unknown/NA	13,934	8,177	24.4	14.3
Total	57,152	57,152	100.0	100.0

2.3 Summary

The analysis of five years of police-reported crash data has shown a number of differences between rear end crashes and other crash types. Rear end crashes are *less* likely to occur in country areas, at night, on weekends, and on undivided roads. They are also less likely to result in serious or fatal injuries. Rear end crashes are *more* likely to occur at or near cross roads, during peak traffic times, in daylight, on level roads rather than on slopes or at the bottom of hills, and on straight roads rather than curved roads.

A number of the characteristics associated with the occurrence of rear end crashes reflect greater traffic density. Specifically, this explanation can account for the relatively lower number of rear end crashes in country areas, at night, on weekends, and on undivided roads, and for the relatively higher frequency of rear end crashes during peak traffic times and daylight hours.

The greater frequency of rear end crashes at or near intersections is likely to be due to the types of traffic conflicts present at intersections. Approaching an intersection, one is more likely to encounter stationary or slowing traffic than when travelling on a midblock section of road. This over-representation of rear end crashes at intersections is likely to be the reason for the over-representation of rear end crashes at traffic signals, although the higher traffic density on roads featuring traffic signals would also be a contributing factor.

It is interesting to note that rear end crashes are under-represented on curved roads (including curved roads causing a restriction of vision), on sloping roads and at the bottom of hills. This could be due to road engineering practices that aim not to place intersections at such sites. It could also be due to drivers being more attentive as they steer through a curved section of road. It is also interesting to note that wet roads and rain do not increase the likelihood of rear end crashes relative to other crash types.

The analysis of TARS data also revealed that inattention is the error most commonly attributed by police to drivers responsible for rear end crashes, with following too closely the next most common. Excessive speed is rarely identified as a cause of rear end crashes (0.2%). However, this figure is likely to underestimate the occurrence of crashes involving excessive speed. This underestimation of the role of speed in crashes, which occurs for all crash types, is due to the difficulty inherent in reconstructing crash events to obtain a legally sustainable estimate of travelling speed before the crash.

A final point to emerge from the comparison of rear end crashes with other crash types is that the former are under-represented with regard to serious or fatal injuries. Rear end crashes are more likely than other crash types to only result in injuries that can be treated adequately by a private doctor.

With regard to comparisons between vehicles that were striking and those that were struck in rear end crashes, the main differences appear to be that striking vehicles are more likely to be driven by males, young drivers and drivers on provisional licences. This is consistent with notions that young, male drivers represent a problematic group of drivers who are often crash-involved and also tend to be responsible for their crashes (Williams & Shabanova, 2003).

3 In-depth crash analysis

3.1 Introduction

Another means of examining rear end crashes is to use information collected through in-depth crash investigations. Beginning in April 2002, CASR has been conducting an in-depth investigation of metropolitan road crashes from which an ambulance has transported at least one person. To the end of February 2005, 286 crashes have been investigated, 47 of which (16.4%) were rear end collisions. That this is an under-representation of rear end crashes relative to police-reported crashes discussed in the previous section is likely to be due to the requirement of ambulance transport for the in-depth study and the low levels of injury severity usually associated with rear end crashes.

For the analysis that follows, nine of the 47 crashes were excluded. Seven were excluded because the struck vehicle was parked, and two were excluded because the striking vehicle was a pedal cycle. Information about the remaining 38 rear end crashes is presented in this section of the report, with the factors contributing to the causation of these crashes being discussed in detail. The ability to provide such detailed accounts of crash causation, not possible when using mass crash data such as that contained in TARS, is one of the main strengths of the in-depth crash methodology.

3.2 Method

Road crashes eligible for inclusion in the metropolitan in-depth study were those occurring on public roads in the metropolitan area to which an ambulance was called and for which at least one person was transported to hospital. Notification of crashes was obtained by monitoring ambulance radio frequencies and also occurred through pager notification by the South Australian Ambulance Service.

CASR staff members were available on call to attend crash scenes during the day five days per week and some evenings until midnight. These additional times were selected as on-call periods following an examination of the time of day distribution of calls for an ambulance to attend road crashes in the study area during the previous year.

The on-call team attempted to reach the scene of the crash before the vehicles involved were moved. As we never requested, or desired, permission to exceed posted speed limits when travelling to a crash scene, it was not possible to achieve this aim in some cases. Occasionally, further investigation of a crash was abandoned if there was not sufficient evidence available at the scene.

The information collected on each case included:

- photographs of the crash scene and vehicles involved
- audio-visual record of the crash scene in selected cases
- details of the road environment, including traffic control measures
- a site plan of the crash scene and vehicle movements in the crash
- details and measurements of the vehicles involved
- interviews with crash participants, witnesses and police
- information on the official police vehicle crash report, and
- injury data for crash participants who attended major metropolitan hospitals

3.3 Results: General

This section provides details of the nature of the sample of rear end crashes investigated as part of the metropolitan in-depth crash study. Variables examined include day of week, time of day, speed limit zones, government authority responsible for the road, presence of median on the road, number of road lanes, weather conditions, crash injury severity, injury severity by seating position, vehicle type, vehicle age, movement of struck vehicles, driver age, driver sex, licence status of drivers, seatbelt use, familiarity with the road, previous involvement of drivers in crashes, and previous involvement in rear end crashes. Following this background information on the crashes investigated, Section 3.4 provides an examination of the factors contributing to the causation of the crashes.

3.3.1 Day of week

Table 3.1 shows the day of week distribution of rear end crashes investigated during the study. The crashes investigated were not representative of day of week of rear end crashes in general, with weekend days unrepresented, as a consequence of the distribution of on-call times.

Table 3.1
Rear end crashes investigated by day of week

Day of week	Number	Percent
Monday	10	26.4
Tuesday	8	21.0
Wednesday	8	21.0
Thursday	5	13.2
Friday	7	18.4
Saturday	0	0.0
Sunday	0	0.0
Total	38	100.0

3.3.2 Time of day

Table 3.2 shows the time of day distribution of the rear end crashes investigated in the study. Due, again, to the distribution of on-call times by time of day, an under representation of crashes between 6pm and 6am is apparent in the study sample.

Table 3.2
Rear end crashes investigated by time of day

Time of day	Number	Percent
0000-0559	0	0.0
0600-1159	11	28.9
1200-1759	25	65.8
1800-2359	2	5.3
Total	38	100.0

3.3.3 Road characteristics

In most of these rear end collisions (82%), the speed limit at the site was 60 km/h. There were two collisions at sites where the speed limit was 50 km/h and four where the speed limit was 70 km/h or more. One rear end collision occurred at a site where road works were in progress, with a speed limit of 25 km/h (Table 3.3).

Table 3.3
Rear end crashes investigated by speed limit zone

Speed limit (km/h)	Number	Percent
25	1	2.6
50	2	5.3
60	31	81.6
70	3	7.9
80	1	2.6
Total	38	100.0

Most of the rear-end crashes in this study (87%) occurred on main roads under the control of the Department for Transport, Energy and Infrastructure (DTEI). The remaining crashes were divided between roads under the control of the Adelaide City Council or other Local Government Authorities (Table 3.4).

Table 3.4
Rear end crashes investigated by government authority responsible for the road

Authority for the road	Number	Percent
DTEI	33	86.9
Adelaide City Council	2	5.3
Other Local Govt. Authority	3	7.9
Total	38	100.0

Approximately three quarters (73.7%) of these rear end crashes occurred on roads having a raised median. The majority of crashes (79%) also occurred on roads with two or more lanes of traffic in each direction of travel (Table 3.5). All of the multi-lane roads were the responsibility of DTEI.

Table 3.5
Rear end crashes investigated by number of traffic lanes

Number of lanes	Number	Percent
One lane each direction	8	21.1
Two lanes each direction	19	50.0
Three lanes each direction	8	21.1
Four lanes each direction	3	7.9
Total	38	100.0

More than 80 percent of the rear end crashes occurred on roads where the vertical alignment was level (see Table 3.6). With regard to horizontal alignment, close to 90 percent of the crashes occurred on straight roads (see Table 3.7).

Table 3.6
Rear end crashes investigated by vertical alignment

Vertical alignment	Number	Percent
Level	31	81.5
Slope up	3	7.9
Slope down	2	5.3
Crest	2	5.3
Total	38	100.0

Table 3.7
Rear end crashes investigated by horizontal alignment

Horizontal alignment	Number	Percent
Straight	34	89.5
Left bend	3	7.9
Right bend	1	2.6
Total	38	100.0

3.3.4 Weather and lighting characteristics

Due to the on-call times for crash investigation, the majority (95%) of rear end crashes investigated occurred during daylight hours. Two crashes were investigated at night. In both of these crashes, the carriageway was illuminated by street lights. Table 3.8 shows the prevailing weather conditions noted by at-scene crash investigators. Rain was not a common feature of the rear end crashes investigated.

Table 3.8
Rear end crashes investigated by weather conditions

Weather conditions	Number	Percent
Fine	26	68.4
Overcast	9	23.7
Raining	2	5.3
Windy	1	2.6
Total	38	100.0

3.3.5 Crash injury severity

There were 102 crash participants involved in the 38 rear end crashes investigated. The crash participants consisted of 74 drivers (36 striking, 38 struck), two motorcycle riders (both striking) and 26 vehicle passengers (12 striking, 14 struck). The maximum level of injury severity for crash participants resulting from rear end collisions, in terms of treatment required, was most commonly hospital treatment, with a total of 45 percent of vehicle drivers, riders or passengers being transported by ambulance to hospital. The average length of time in hospital for treatment was 3.4 hours, ranging between a minimum of less than one hour to a maximum of five hours. Only one vehicle occupant required hospital admission as a result of involvement in a rear end collision. In this case, the centre rear seat passenger of a striking vehicle was admitted and hospitalised for 15 days. This vehicle occupant's hospital admission was the result of a bowel perforation most likely caused by the centre lap belt. Forty three percent of crash participants were uninjured.

The injury severity for all crash participants, divided into those occupying struck or striking vehicles is shown in Table 3.9. It can be seen that the occupants of struck vehicles were more likely to require hospital treatment (58%) than the occupants of striking vehicles (34%).

Table 3.9
Rear end crash participants by crash injury severity

Crash injury severity	Striking	Striking %	Struck	Struck %
Fatal	0	0.0	0	0.0
Admitted to hospital	1	2.0	0	0.0
Treated at hospital	16	32.0	30	58.0
Treated by doctor/minor	5	10.0	6	11.5
No injury	28	56.0	16	30.5
Total	50	100.0	52	100.0

The information provided in Table 3.9 can be further categorised according to seating position (Table 3.10). It can be seen that over half of the vehicle occupants requiring hospital treatment were the drivers of struck vehicles.

Table 3.10
Rear end crash participants by crash injury severity

Occupant position	Admitted	Hospital Treated	Doctor/minor	No injury
Striking:				
Driver/rider	0	13	4	21
Left front passenger	0	1	0	3
Left rear passenger	0	1	0	1
Centre rear passenger	1	0	1	0
Right rear passenger	0	1	0	3
Total	1	16	5	28
Struck:				
Driver	0	24	3	11
Left front passenger	0	3	3	4
Left rear passenger	0	2	0	1
Centre rear passenger	0	0	0	0
Right rear passenger	0	1	0	0
Total	0	30	6	16
Overall total	1	46	11	44

The most common injury types that led crash participants to seek medical treatment at a hospital were neck pain or headache. Although these injury types were seen across struck and striking vehicle occupants, they were more common among those in struck vehicles. Eighteen drivers and three passengers of struck vehicles sought medical treatment for neck pain or headache, compared to only two drivers and three vehicle occupants of striking vehicles.

Chest or shoulder pain that was associated with seatbelt usage was the next most common injury type for participants involved in rear end collisions. This type of injury was evenly distributed between striking vehicle and struck vehicle occupants. The two motorcycle riders sustained abrasions and contusions resulting from contact with the ground after the initial impact.

3.3.6 Vehicle type

Of struck vehicles, 90 percent were cars or car derivatives. Less than 66 percent of striking vehicles were car derivatives, however, with greater involvement of large trucks, passenger buses and motorcycles than was the case among struck vehicles (see Table 3.11). There was little difference in vehicle age between struck or striking vehicles. The median age of striking vehicles was 11.5 years and that of struck vehicles was 12.5 years. The median age for vehicles on South Australian roads is 11.6 (Australian Bureau of Statistics, 2005).

Table 3.11
Vehicle types involved in the rear end crashes investigated

Vehicle type	Striking vehicle	Struck vehicle	Striking (%)	Struck (%)
Car or car derivative*	25	34	65.8	89.5
SUV	2	1	5.3	2.6
Van	3	2	7.9	5.3
Small truck	0	1	0.0	2.6
Large truck	3	0	7.9	0.0
Bus	3	0	7.9	0.0
Motorcycle	2	0	5.3	0.0
Total	38	38	100.0	100.0

* Sedans, hatches, station wagons

3.3.7 Movement of the struck vehicles

Thirty-five of the struck vehicles in this study (92.1%) were stationary at the time of being struck. In 15 of these cases, the struck vehicle was stationary at a signalised intersection. Although the majority of these crashes occurred within close proximity to the intersection, approximately one third of the struck vehicles were stopped more than 100 metres away from the intersection due to traffic congestion, the furthest distance being approximately 400 metres.

In nine other cases, the struck vehicle had become stationary on a major road while waiting for oncoming traffic to clear before undertaking a right hand turn into another road. In one case, the struck vehicle had moved through a signalised intersection but became stationary in response to traffic congestion ahead. Other reasons for struck vehicles becoming stationary included: a long line of congested traffic ahead without the presence of a signalised intersection, stopping at a pedestrian-activated crossing, and one case where the struck vehicle was waiting in a 'Turn Left with Care' lane. Additionally, there were three cases in which vehicles became stationary due to unexpected events ahead of them that required that they stop.

There were only three cases in which the struck vehicles were moving at the time of the rear-end collision. In each of these cases, the vehicle was travelling straight ahead, rather than turning, when it was struck from behind by a faster moving vehicle.

3.3.8 Age and sex of the drivers/riders

Clear differences were seen in the sex and age characteristics of the drivers of striking vehicles when compared with drivers of vehicles that were struck. Although the sex distribution of drivers in struck vehicles was close to being evenly divided between males (47%) and females (53%), the driver of a striking vehicle was more than twice as likely to have been male (71%) rather than female (29%). The age distribution of drivers revealed a greater likelihood of being involved in a rear-end crash as a striking driver when young. Half of all striking drivers were aged between 16 and 35. For the drivers of struck vehicles, drivers in this age group only accounted for 29 percent. Drivers aged 25 years or less represented more than 26 percent of drivers of striking vehicles but only 13 percent of struck drivers. Drivers over the age of 55 years were twice as likely to have been driving a struck vehicle rather than a striking vehicle. Table 3.12 shows the age distributions of drivers of striking vehicles and drivers of struck vehicles.

Table 3.12
Age of drivers involved in the rear end crashes investigated

Driver age	Striking vehicle	Struck vehicle	Striking (%)	Struck (%)
16-25	10	5	26.3	13.2
26-35	9	6	23.7	15.8
36-45	7	9	18.4	23.7
46-55	7	8	18.4	21.0
56-65	2	7	5.3	18.4
66-75	2	2	5.3	5.3
76-85	1	1	2.6	2.6
Total	38	38	100.0	100.0

3.3.9 Licence status of drivers/riders

There was no significant difference in motor vehicle licence status between the drivers of striking vehicles and the drivers of struck vehicles. Table 3.13 shows the breakdown of drivers by licence category. Ten of the drivers of striking vehicles held additional licences beyond a full car licence. These included three drivers who held a passenger transport licence, two drivers who held a motor cycle licence, two who held a semi-articulated vehicle and motorcycle licence, two who held road train licences and one who held a rigid truck licence. Two drivers of struck vehicles held a small truck licence in addition to a full car licence.

Table 3.13
Driver's licence status of drivers involved in rear end crashes

Driver's licence status	Striking driver	Struck driver
Full licence	34	35
Provisional licence	4	3
No licence	0	0
Total	38	38

3.3.10 Seatbelt use

Seat belt usage was checked and recorded at the scene of each crash investigated, including the type of belt provided and objective evidence of usage, such as scuff and/or kink marks. This information was supplemented by self-reported usage at the scene and in follow-up crash participant interviews. In each of the rear end cases investigated, all vehicles involved in the collision, excluding the motorcycles, were fitted with seat belts. In all but five cases, the drivers and vehicle occupants were provided with inertia reel seat belts. Two truck drivers were provided with two point static lap belts, one driver and passenger of an early model vehicle were provided with three point static seat belts, and one centre rear seat passenger was provided with a two point static lap belt. Objective and self-reported evidence show that restraint usage was extremely high among drivers and vehicle occupants in all crashes. There were only two vehicle occupants who were not restrained at the time of the rear end collision, both of whom were drivers of striking trucks. In both cases, the drivers stated that although they routinely used a restraint when driving a standard motor vehicle, they never wore one while driving a truck.

3.3.11 Familiarity with the road

Crash participants who agreed to a post-crash interview were asked questions related to frequency of use and knowledge of the road where the collision occurred. Of those drivers who participated in interviews, 48 percent of struck drivers travelled on the road daily, compared with 30 percent of striking drivers (see Table 3.14).

Table 3.14
Self-reported familiarity with road of drivers
involved in the rear end crashes investigated

Familiarity	Striking vehicle	Struck vehicle	Striking (%)	Struck (%)
Drive daily	6	12	30.0	48.0
Familiar	10	11	50.0	44.0
Not well known	4	1	20.0	4.0
No knowledge	0	1	0.0	4.0
No interview given	18	13	-	-
Total	38	38	100.0	100.0

3.3.12 Previous involvement in road crashes

Levels of previous involvement in road crashes were ascertained for the drivers in the rear end collisions by cross-referencing their driver's licences with crash records contained within the TARS database. The use of TARS enabled determination of drivers' previous involvement in police-reported crashes in South Australia between 1981 and 2004. It also enabled examination of responsibility for the crash.

Table 3.15 shows the number of crashes each of the drivers had recorded in the TARS database prior to their involvement in the rear end crash investigated. There was very little difference between drivers of striking vehicles and drivers of struck vehicles with regard to previous crash involvement, although it must be noted that the younger average age of the drivers of striking vehicles means that they would have had less previous exposure to crash risk than the drivers of struck vehicles. More than 50 percent of all drivers had no recorded crash history prior to their involvement in this collision. Around nine percent of drivers involved in the study had a history of four or more crashes. With regard to responsibility for previous crashes, drivers of striking vehicles were deemed by the investigating police officers to have been at fault in 75 percent of their crashes, compared to struck drivers who were deemed to have been at fault in 63 percent of cases.

Table 3.15
Previous crash involvement of drivers involved in the rear end
crashes investigated, by crash responsibility

Number of crashes	Striking vehicle	Struck vehicle	Striking (%)	Struck (%)
None	22	19	58.0	50.0
One	6	7	15.7	18.4
Two	7	6	18.4	15.7
Three	0	2	0.0	5.3
Four	3	2	7.9	5.3
Five	0	2	0.0	5.3
Total	38	38	100.0	100.0

3.3.13 Previous involvement in rear end crashes

In addition to the analysis of previous involvement in crashes overall, the TARS database was also checked to determine the number of striking and struck drivers who had been involved in previous rear end crashes. Eleven drivers of striking vehicles had a history of 14 previous rear end crashes. Of these 14 crashes, it was found that 12 (86%) were considered by police to be the result of an error by this driver. The most common faults identified by police in these crashes were inattention, driving too closely and driving without due care. In contrast, 12 drivers of struck vehicles had a history of 22 previous rear end crashes. Of these 22 crashes, only eight (36%) were adjudged by police to have occurred as a result of driver error for this driver. The greater likelihood of the drivers of striking vehicles being responsible for previous rear end crashes was statistically significant ($\chi^2_{(1)} = 8.4$, $p <$

.01). Individual driver crash history will be discussed in more detail, where relevant, as the rear end crashes are explored further in the next section of this report.

3.4 Results: Contributing factors to rear end crashes

During the course of the investigation of the collisions, the various factors that may have contributed to the crash were examined. This evaluation was based on evidence collected at the crash scene and information collected in interviews with drivers, occupants, police and witnesses following the collision.

Many of the rear-end crashes investigated were found to share common contributing factors. Included among these were issues related to road infrastructure and others related to human factors. The following section provides a summary of the common factors contributing to the rear end crashes investigated, with crash examples given for each factor. As some crashes had more than one contributing factor, individual crashes may be discussed on more than one occasion. The contributing factor of following too closely, often cited by police as causing rear end crashes, is not included in this section because its role in the crashes was difficult to establish with any confidence. Significant prior crash records of drivers and crash sites are included in crash descriptions where relevant.

3.4.1 Inadequate allocation of attention

There is considerable evidence to suggest that many of the rear end crashes investigated occurred as a result, at least partly, of the inadequate allocation of attention by the striking driver. Inadequate allocation of attention occurred in a number of different ways. One such way involved the failure to allocate sufficient attention to the overall driving task. Drivers in these cases were pre-occupied with something else (e.g. emotional distress) and were not concentrating on driving. These crashes are classified here as being due to 'inattention'. A second form of inadequate allocation of attention was that of 'distraction'. In these cases, the drivers were involved in a crash because they were distracted by visual stimuli in the environment, either outside or inside the vehicle (e.g. street directory, lighting a cigarette), which meant that they were not looking at the road. Thirdly, inadequate allocation of attention often resulted from a failure to adequately divide attention between two driving-related tasks. Such crashes would result, for example, from drivers looking at rear vision mirrors and noticing too late that traffic ahead had become stationary. A final sub-category relates specifically to lane changes in which the drivers failed to observe that their lane change was unsafe because of slow or stationary traffic ahead of them in the lane into which they were changing. These crashes therefore involved *adequate* division of attention between traffic directly ahead in the original lane and traffic behind in the new lane but insufficient allocation of attention to observing traffic ahead in the new lane.

There were several cases in which inadequate allocation of attention was suspected but was unable to be confirmed through interviews. These cases have been omitted from this section.

INATTENTION

There were three cases, which were classified as being the result of 'inattention'. That is, the drivers did not allocate enough attention to the driving task. These cases are described below.

Crash M070:

The striking vehicle was being driven by a driver who reported that her attention to the driving task was severely impaired due to external stressors that had been escalating in the days leading up to the collision. She took little evasive action prior to colliding with a vehicle that had been stationary for some time. For a full description of this crash, see Section 3.4.3.

Crash M134:

The struck vehicle became stationary behind other vehicles at a red traffic signal and was stationary for several seconds before it was struck by a vehicle under braking. The driver of the striking vehicle stated that the traffic ahead appeared to become congested suddenly without her being aware of it. She reported that the collision must have occurred as a result of inattention but was unable to account for her lapse in concentration prior to the collision.

Crash M162:

The driver of the striking vehicle had been aware that a vehicle ahead had slowed and was indicating to turn right as he approached. The road was relatively free of other traffic and the driver stated that he expected the vehicle to have negotiated the turn before he arrived at its position. He made no further observation of that vehicle. The driver stated further that he was unaware of his involvement in the collision until the airbag deployed. He could not account for failing to observe that the vehicle was still in position, waiting to turn.

DISTRACTION

There were eight cases in which the drivers of the striking vehicles were distracted from the driving task, and specifically from the observation of other traffic. The distracters included objects or events either within the vehicle or part of the road or roadside environment. The distractors inside vehicles included a street directory (on two occasions), a bus timetable, a cigarette, and a mobile phone. Distractors outside of the vehicle included a new housing development, road workers, and a load of plastic bottles spilled on the road.

Crash M007:

The driver in this case was an interstate visitor who had just commenced her road journey back to Sydney. She was driving her own vehicle. The driver was uncertain of the correct path to get to the South Eastern Freeway and was seeking assistance from the left front seat passenger, who was giving directions from an open street directory. The driver was aware of a vehicle ahead of her that was travelling at a normal speed. The driver of the striking vehicle glanced down at the open street directory for an estimated two to three seconds. During this time, the driver ahead indicated his intention to turn right into a side street, brought the vehicle to a stop, and was waiting for oncoming traffic to clear. On redirecting her attention to the road ahead, the driver of the striking vehicle was confronted with the stationary vehicle, with little time to undertake evasive action, and a collision occurred.

Crash M042:

The striking vehicle in this case was a large metropolitan passenger bus being driven by a bus driver who was familiar with the road. The traffic ahead of the bus was congested but moving, when the driver of the bus directed his attention to a bus timetable positioned on the dashboard near the steering wheel. On returning his attention to the roadway ahead, the bus driver was confronted with a line of stationary vehicles that had stopped for a red traffic signal at an intersection. The bus driver attempted to brake but was unable to avoid a rear end collision with the vehicle ahead.

Crash M075:

The attention of the driver of the striking vehicle in this case was directed to other activities, including lighting a cigarette, when he accelerated into the rear of a stationary vehicle ahead of his. For a full description of this crash, see Section 3.4.3.

Crash M102:

The driver of the striking vehicle in this case reported that he had been distracted from the driving task and that this was not an uncommon feature of his driving habits. The vehicle was in the right lane, travelling behind at least two other vehicles that were approaching a signalised intersection with a green light. The striking driver's attention was drawn to a new housing development to the left of the carriageway for an unknown period of time. On redirecting his attention ahead, the driver was confronted with the two vehicles that were now stationary at a red traffic signal, with less than two metres between his and the last stationary vehicle. The driver braked but was unable to avoid a collision with this vehicle. The driver of the striking vehicle had a history of four crashes in the previous six years, including two rear end collisions in 2000. The driver was deemed by police to have been at fault in both of these rear end collisions due to 'following too closely'.

Crash M113:

The driver of the striking vehicle in this case had been using a hand held mobile phone at the time of the collision. The call was still connected when bystanders offered assistance to the injured driver. For a full description of the crash, see Section 3.4.4.

Crash M127:

The driver of the striking vehicle in this case was travelling along a single lane road that was unfamiliar to him. He was accompanied by three peers and together they were attempting to give him directions to a takeaway food venue that none of them knew well. The front seat passenger was providing directions from an open street directory and the driver was occasionally glancing toward the book as he drove. For full details of the crash, see Section 3.4.6.

Crash M152:

The collision occurred on a single lane local road immediately beyond a rough, slightly raised railway crossing. As the driver of the striking vehicle approached the railway crossing, he was confronted with a number of road work vehicles and road workers who were erecting signs at the edge of the road. He reported being distracted by the number of workers and the noise they were making as the signs were thrown from their vehicles. For a full description of this crash, see Section 3.4.6.

Crash M256:

The striking vehicle in this case was the fourth in a platoon of vehicles in the left lane. The vehicles moved together through a signalised intersection on a green light without needing to alter their speed. As the platoon of vehicles negotiated a blind left hand bend, the drivers were confronted with a load of plastic bottles that had spilled onto the road. All of the drivers reported that the bottles were a considerable distraction as they travelled over them or were flicked up onto their vehicles by the preceding vehicle. After negotiating a path over the bottles, the drivers were then confronted with a stationary vehicle ahead and braked to a stop without incident. The striking vehicle, however, was still travelling through the hazard as it exited the bend and approached the stationary vehicles immediately ahead. The driver attempted to brake but was unable to avoid hitting the rear vehicle, which subsequently struck the next vehicle in the line (see Figure 3.1).

Figure 3.1
Vehicles involved in Crash M256

INADEQUATE DIVISION OF ATTENTION

There were five crashes that were classified as being the result of inadequate division of attention. These cases are described below.

Crash M087:

The two vehicles had become stationary in a 'Turn Left With Care' lane and were attempting to turn into traffic on a busy road. On seeing a gap in the through traffic, the driver of the striking vehicle accelerated and collided with the rear of the still stationary lead vehicle. The driver of the striking vehicle stated that the gap was adequate for both vehicles to enter the flow of traffic and so assumed that the lead vehicle had moved forward but did not look ahead to confirm this before accelerating.

Crash M111:

The striking vehicle in this case was a large truck carrying nine tonnes of crushed concrete. The driver of the vehicle stated that he was worried about the time he needed to complete a work task and potential delays in his progress that could be caused by impending inclement weather. The driver was travelling in the left lane and was aware of a vehicle some distance ahead of him. As the truck approached a pedestrian-activated crossing, the lights changed to amber and then red. The truck driver diverted his attention from the road as he looked for pedestrians. On seeing that there were no pedestrians in the vicinity, he then directed his attention again to the road ahead where he was confronted with the stationary vehicle at the crossing. The driver braked but was unable to avoid the collision. He stated that he expected the vehicle ahead to have travelled through the crossing and so he did not look at it again until immediately before the collision. It appeared from the investigation that the truck driver intended to drive through the red signal if no pedestrians were present. This would mean that intent to break the law also contributed to the crash but this intent on the part of the driver could not be ascertained with certainty. The driver of the striking vehicle had a history of three crashes in the previous ten years. In two of these, the driver was deemed by police to have been at fault, both times because of 'inattention'. All three of these crashes occurred when driving a car rather than a truck.

Crash M132:

The striking vehicle in this case was a large gas transport truck that was not carrying a load at the time of the collision. The truck was travelling down a descending road in the centre of a platoon of vehicles that was travelling at the speed limit. The driver considered that a safe distance was maintained between his vehicle and the vehicle directly ahead at that time. He noted that there were road works some distance ahead and was seeking to change lanes. His attention was directed to his left side mirrors for an estimated two to three seconds as he judged the space available to undertake the manoeuvre safely. He realised that there was no available space to undertake the manoeuvre and elected to stay in the lane he was travelling in. On redirecting his attention to the road ahead, he was confronted with vehicles that were now almost stationary because of a red traffic signal much further ahead. He braked solidly but was unable to avoid colliding with the vehicle directly ahead that, in turn, struck the rear of a stationary vehicle ahead of it.

Crash M166:

The driver of the striking vehicle in this case was travelling in a platoon of vehicles. The traffic ahead of him was moving when he diverted his attention to his rear vision mirror. On redirecting his attention ahead, he was confronted with a long line of stationary vehicles that were now queuing for the signalised intersection four hundred metres ahead. He braked but was unable to avoid the collision. For more details of this crash, see Section 3.4.4 'Parking on arterial roads').

Crash M174:

The driver of the striking vehicle involved in this collision was attempting to exit a designated right turn lane and enter the through lane to his left in heavy traffic. The driver was familiar with the road and reported that he had been swapping between the centre and right lanes on several occasions in the lead up to the collision. He stated that he had undertaken this manoeuvre on other occasions without incident but that, on this occasion, the traffic was more congested due to road closures elsewhere. The driver was travelling behind a long line of vehicles that were travelling at a constant speed when he directed his attention to the left side mirror to look for an opening to once again change lanes. Despite indicating his desire to change lanes, no gap became available. The driver directed his attention back to the road ahead and was confronted by the now stationary vehicles that were queuing some distance from the signalised intersection. The driver braked hard but was unable to avoid a collision.

UNSAFE LANE CHANGES ASSOCIATED WITH INADEQUATE ALLOCATION OF ATTENTION

There were four crashes in which drivers made lane changes that, due to inadequate allocation of attention, resulted in rear end collisions with vehicles ahead of them. These crashes are described below.

Crash M168:

This collision occurred just past a railway crossing. Prior to the collision, the vehicles involved had been held up at the railway crossing by two consecutive trains before being able to continue through. The driver of the striking vehicle reported at the scene that he had been frustrated by this long delay. There were vehicles ahead of the striking vehicle in both lanes, including two vehicles in the right lane. The lead of these two vehicles indicated an intention to turn right into a side street approximately 200 metres beyond the railway crossing. Both vehicles were stationary for some time. The striking vehicle moved into the right lane from the left and, on entering the lane, the driver was confronted with the two stationary vehicles. The driver of the striking vehicle had not been aware of the presence of the stationary vehicles before changing lanes. The driver braked but was unable to avoid colliding with the rear of the two vehicles, which subsequently struck the vehicle ahead. The driver of the striking vehicle had a history of one previous rear end crash in 2001. The driver was deemed by police to have been at fault in this previous collision due to 'driving too closely'.

Crash M175:

The driver of the striking vehicle had limited experience driving in metropolitan Adelaide. While travelling up a steep gradient, the driver became aware of a vehicle ahead of him that he claims was making frequent lane changes. He moved into the right lane to avoid conflict with this vehicle. The driver of the striking vehicle was unaware that a collision was imminent with a stationary vehicle in the right lane that was queued at an intersection, and so he took no evasive action. He stated that he was not aware that he was approaching a signalised intersection or that there was a vehicle in the right lane.

Crash M249:

The striking vehicle was travelling in the left of two lanes behind other vehicles when the driver noted the vehicle ahead was slowing down and indicating to turn left into a side street. The driver decided to change into the right lane and diverted his attention to his right side mirror to check for a gap in the traffic. The driver successfully changed into the right lane but was immediately confronted with a stationary vehicle waiting to turn right. The driver had little time to undertake evasive action and collided with the rear of the stationary vehicle. Although the stationary vehicle had been waiting to execute the turn for approximately one minute, the driver of the striking vehicle stated that he was not aware of the stationary vehicle's presence at any time prior to changing lanes.

Crash M286:

The striking vehicle was a large metropolitan passenger bus that had no passengers at the time of the collision. The bus driver had been travelling in the left lane behind another passenger bus when the driver of that vehicle indicated its intention to stop and collect passengers. The driver of the striking vehicle looked in his right rear mirror to check for vehicles that might be travelling behind him as he negotiated a lane change. On entering the right lane, the driver was immediately confronted with vehicle that was stationary while the driver waited to execute a right turn into a side street. The driver was not aware of the presence of the stationary vehicle before changing lanes. The bus driver veered left and braked but was unable to avoid the stationary vehicle. The driver of the striking vehicle had a history of four crashes, including one rear end collision in 1986. In all of these crashes, the driver was driving a taxi. The driver was deemed by the police to have been at fault in the previous rear end collision due to 'inattention'.

3.4.2 No designated right turn lanes

Eleven of the 38 collisions included in this study occurred when a vehicle became stationary while waiting to turn right into another road and was struck by a vehicle travelling behind. In each of these cases, the drivers of the turning vehicles had indicated their intentions appropriately. Seven of these collisions occurred on four lane carriageways, including five on major arterial routes that carry traffic volumes in the vicinity of 19,000-33,000 vehicles per day (Annual Average Daily Traffic Estimates - 24 hour 2 way flows. TSA Transport Information Management Section - July 2002).

Designated right turn lanes allow right hand turn movements for vehicles to occur in a more protected manner and additionally allow for freer, unobstructed movement of through vehicles. There was one case in which a designated turning lane was provided but the storage capacity of the lane was not adequate to cater for the volume of traffic that was using the lane. The collision in this case occurred when the struck vehicle was partly in the through lane.

REAR END COLLISIONS WITH RIGHT TURNING VEHICLES ON ARTERIAL ROADS

There were five crashes involving rear end collisions with right turning vehicles on arterial roads. They are described below, and the average daily traffic counts for each road are provided.

Crash M003:

Average daily traffic measurement for the carriageway: 24,200 vehicles.

The turning vehicle was stationary in the single northbound lane waiting for oncoming traffic to clear before undertaking a turn into a side street. It was struck from behind by a vehicle travelling straight ahead. It is likely that parked vehicles at the kerbside may have reduced the width of carriageway available for traffic but this could not be confirmed. The driver of the striking vehicle failed to see that the vehicle ahead had become stationary and there was no evasive action taken prior to the collision. The road at this crash site has undergone extensive modification since the collision and now provides two lanes for through traffic and a designated right turn lane.

Crash M007:

Average daily traffic measurement for the carriageway: 24,000 vehicles.

The turning vehicle had been in the right lane for some time before becoming stationary, as the driver waited for a safe opportunity to turn right. For a full description of this crash, see Section 3.4.1 ('Driver distraction').

Crash M061:

Average daily traffic measurement for the carriageway: 24,600 vehicles.

The struck vehicle was stationary at an intersection while the driver waited for a gap in oncoming traffic that would allow a right turn. For a full description of the crash, see Section 3.4.4 ('Parking on arterial roads').

Crash M154:

Average daily traffic measurement for the carriageway: 33,100 vehicles.

The turning vehicle was in the right lane for several hundred metres before the driver indicated his intention to move into a designated right turn lane. The turning lane catered for vehicles entering a large retail outlet. The lane was congested with a large number of vehicles and so the turning vehicle was forced to wait in a position that partially obstructed the normal flow of traffic in the right through lane. The motorcyclist travelling behind the turning vehicle, who is likely to have anticipated clearance of the through lane, collided with the rear of the turning vehicle. The rider skidded across both lanes in front of other through traffic before coming to rest on the raised kerb (see Figure 3.2). The young male rider had a history of four crashes in the previous ten years, one of which was a rear end collision. The rider was deemed by police to have been at fault in three of these four collisions, two as a result of inattention and one as a result of driving without due care. All of the previous crashes occurred when driving a car rather than as a motorcyclist.

Crash M286:

Average daily traffic measurement for the carriageway: 18,700 vehicles.

For a description of this crash, see Section 3.4.1 ('Unsafe lane changes associated with inadequate allocation of attention').

REAR END COLLISIONS WITH RIGHT TURNING VEHICLES ON NON-ARTERIAL, SINGLE LANE ROADS

Four rear end collisions occurred where a right turning vehicle had become stationary on a non-arterial, single lane road. In all but one of these cases, the carriageway was not wide enough to allow through vehicles to pass on the left of the turning vehicle. These four crashes are listed below.

Crash M070:

The struck vehicle in this case had become stationary as a result of another vehicle that was stationary while the driver waited to undertake a right turn into a side street. The lane width was four metres, making it impossible for vehicles to pass the turning vehicle on the left. For a full description of this crash, see Section 3.4.3.

Crash M127:

The driver of the struck vehicle in this case was waiting to turn right from a single lane road. For full details of the crash, see Section 3.4.6.

Crash M152:

The collision occurred on a single lane local road immediately beyond a rough, slightly raised railway crossing. For a full description of the crash, see Section 3.4.6.

Crash M162:

This collision occurred on a wide straight road that allowed good vision of vehicles ahead. The struck vehicle had been stationary for several seconds while the driver waited for a safe opportunity to turn right. For a full description of the crash, see Section 3.4.1 ('Inattention').

Figure 3.2
Crash site for M154 showing the right turn lane and tyre marks associated with the crash

3.4.3 Health issues of drivers of striking vehicles

Five of the striking drivers involved in the rear end collisions had a confirmed health problem that was likely to have played a role in their crash involvement. These included both physical and mental problems and at least two cases involved a drug-related component. No drivers of struck vehicles were found to have any health problems that played a role in their crash involvement. The five crashes involving driver health issues are described below.

Crash M050:

The driver of the striking vehicle had a long-standing and current history of sleep disturbance secondary to significant depression that had escalated over the preceding weeks. The driver was on her way home after attending a medical appointment where she was prescribed a sedative (Stillnox). The driver had obtained the prescription and taken two tablets before her journey home. The vehicle was seen by a witness in a following vehicle to drift across both lanes before accelerating into the rear of a slower moving vehicle ahead of it. The driver had no memory of the collision and this, combined with the drifting across lanes, suggests the possibility that the driver may have fallen asleep at the wheel. Significantly, this driver had a similar crash under the same circumstances one month prior to this collision. Medical reports post-collision noted that the driver had a recent history of suicide attempts but concluded that this collision (M050) was not the result of a suicide attempt.

Crash M070:

The driver of the striking vehicle had a long-standing and current history of both physical and mental health issues. She reported that her mental health status at the time of the collision was very poor as a result of a family break-up and associated difficult custody battle. The driver reported that these issues were her primary concern at the time and a significant distraction immediately preceding the collision. The driver proceeded over a small crest (insufficient to constitute a significant visual obstruction) and collided with the rear of the last of a long line of stationary vehicles that had stopped because the driver of the lead vehicle was waiting to undertake a right hand turn. The driver of the striking vehicle took little evasive action prior to the collision. She is known to have been prescribed antidepressant and anxiolytic (anxiety-reducing) medications at the time of the collision. She was reluctant to discuss the timing of administration of these medications in relation to the collision.

Crash M075:

The driver of the striking vehicle had a long standing and current history of illicit drug use/abuse, including intravenous use of morphine, and reported use of medications prior to driving that is likely to have impaired his driving abilities. He reported that he had consumed 8-10milligrams of Xanax prior to driving on the day of the crash. Xanax is a member of the anxiolytic family and is known to cause increased reaction time and drowsiness (MIMS Australia, 2005). The self-reported dose taken by the driver is at the upper level of daily therapeutic use, and had been consumed over a four hour period. The driver states that his drug usage at the time was escalating, and that he had been taking various drugs including marijuana and methamphetamine, but denied use of these or other substances on the day of the collision. The driver of the striking vehicle in this case was aware that traffic was congested as a result of a signalised intersection ahead and his vehicle had been stationary behind other vehicles for a short period of time. While stationary, the driver's attention was directed to other activities, including lighting a cigarette. The driver of the striking vehicle glimpsed some movement in the vehicle ahead and, while looking down, he accelerated into the rear of this vehicle that had once again become stationary. The driver of the striking vehicle had a history of two rear end crashes in the previous eight years. In both of these cases the driver was deemed by police to have been at fault due to 'inattention'.

Crash M109:

The driver of the striking vehicle in this case had Insulin Requiring Diabetes Mellitus. The driver reported that early in the driving journey he 'felt flat'. The driver misinterpreted the actions of vehicles ahead as they slowly moved forward in a long line of congested traffic. He began to accelerate, colliding with the rear of the forward vehicle that had once again become stationary. Following the rear-end collision, paramedics took a blood glucose reading from the driver and he was subsequently given a glucose drink, suggesting that his blood glucose level was very likely to be below or at the lower level of the normal range (i.e. hypoglycaemic) at the time of the collision. This hypoglycaemia was likely to have impaired his judgement.

Crash M184:

The driver of the striking vehicle in this case was pregnant at the time of the collision (gestation 9 weeks). She reported that she was feeling unwell and was attempting to drive home because of this. She fainted while driving and ran into the rear of a vehicle that was stationary at a red traffic signal. The driver had a history of frequent fainting at this same gestational stage of pregnancy.

3.4.4 Parking on arterial roads

There were three cases in which parked vehicles on the road contributed in some way to the crash occurring. In each of these cases, the road carried high traffic volumes, with a range between 24,000 and 51,000 vehicles per day (Annual Average Daily Traffic Estimates - 24 hour 2 way flows. TSA Transport Information Management Section - July 2002). These three crashes are described below.

Crash M061:

This crash occurred on a major arterial route (average daily traffic of 24,600 vehicles). A truck driver moved his truck into the left lane in response to seeing a vehicle that was stationary while the driver waited to turn right into a side street. The truck driver was confronted with a large parked vehicle and so moved back to the right lane and attempted to drive between the two vehicles but failed, colliding with the vehicle in the right turn lane. The road, recognised as being a major thoroughfare, carries a Clearway restriction for traffic between 1600 and 1800 hours. This collision occurred between 1500 and 1600 hours, a period not covered by the restriction but a time period when traffic volumes at the site are rapidly increasing.

Crash M113:

This crash occurred immediately beyond a sweeping, partially blind, left hand bend on a 70 kilometre per hour speed limit road that carries constant heavy traffic for most times of the day (average daily traffic measurement of 30,200 vehicles). Additionally, the site features merging lanes coming in from another major road on the right. In response to these, there are No Parking zones around the merge lane area. The collision occurred when vehicles came around the bend and were confronted with an unexpected parked vehicle. This vehicle was parked immediately forward of the No Parking area but forced traffic in the left lane to become stationary in the blind section of the bend where parking is prohibited. The driver of the striking vehicle may have reasonably expected the lane to be clear but instead was confronted with stationary vehicles and a collision occurred. As noted earlier (see Section 3.4.1 'Distraction'), the driver was also using a hand held mobile phone at the time of the collision.

Crash M166:

Although this case does not technically involve a parked vehicle, the collision was more likely to happen because of the constant use of the left lane of the road as a parking area by local businesses and their patrons. The stretch of road on which the crash occurred is a major arterial route with an average daily traffic volume of 51,200 vehicles. There is a long designated right turn lane that has good storage capacity for turning vehicles and there are two lanes designated for through vehicles. For the majority of the day, outside of Clearway restrictions between 1630 and 1800 hours, the left lane of the road is congested with parked vehicles, effectively restricting this major route to a single lane that carries a constant large volume of traffic. The driver of the striking vehicle in this instance was inattentive while checking his rear vision mirror (see Section 3.4.1 'Inadequate division of attention'). The driver failed to recognise that the heavily congested lane was slowing in response to traffic queuing for a red signal several hundred metres ahead. The vehicle collided with the rear of the last stationary vehicle in that line, forcing the struck vehicle into the vehicle ahead. This short stretch of road is a common site for rear end crashes, with approximately four such crashes being reported to police in each of the years between 2000 and 2004 (TARS database: 2000=3 2001=4 2002=3 2003=4 2004=4).

3.4.5 Unexpected events on the road

In each of these three cases, the forward vehicle(s) stopped suddenly on the road and the striking vehicle collided with the rear of the vehicle immediately ahead. Although it could be argued that the driver of the striking vehicle was responsible for the collision due to inattention or following too closely, it could also be argued that, given the lack of traffic congestion on the roads involved, the drivers could not have anticipated that their movement would be suddenly halted.

Crash M019:

This crash was due to the combination of the striking driver's vision of the road ahead being restricted by a truck and the unexpected braking of the truck in response to a reversing vehicle in the lane ahead. In this case, the struck vehicle, a small truck, came to a sudden stop on a lightly trafficked road because another vehicle was reversing in the lane ahead. It is thought by the truck driver that the driver of the reversing vehicle had 'overshot' his or her desired turn and chosen to reverse some distance on the road. This driver of the reversing vehicle fled the scene and so could not be interviewed. The driver of the striking vehicle, whose vision ahead of the truck was restricted (see Figure 3.3), failed to recognise that the truck had suddenly stopped until too close to undertake effective braking and so ran into the rear of the stationary truck. The driver of the striking vehicle had a history of two crashes in the previous four years. He was deemed by police to have been at fault in one of these collisions.

Figure 3.3
Truck struck in the rear in Crash M019

Crash M129:

The driver of the struck vehicle in this case had a clear road for several hundred metres ahead. However, a dog ran onto the road and the driver braked suddenly to avoid striking it. The driver of the striking vehicle was not aware of the dog on the road and failed to observe the sudden stopping of the forward vehicle until he was too close to undertake effective braking, running into the rear of the now stationary vehicle ahead.

Crash M256:

The unexpected event on the road in this case was the presence of a stationary vehicle, the driver of which was attempting to retrieve a fallen load of bottles. For a full description of this crash, see Section 3.4.1 ('Distraction').

3.4.6 Miscellaneous infrastructure issues

Three rear end collisions occurred at sites that were complicated by other road features that could have increased the likelihood of such collisions occurring. Although each of these collisions could be argued to have occurred due to other contributing factors, such as inadequate allocation of attention, they may have been less likely to occur if the road feature in question had not been present. These three crashes are described below.

Crash M127:

The collision occurred when a right turning vehicle became stationary on a single lane road. The side street that the vehicle was turning into is situated in the centre of a sweeping right hand bend. Although it was estimated that the site distance around the bend, approximately 50 metres, should have provided adequate distance for a following vehicle to stop, it is possible that a driver unfamiliar with the site may have believed that there was adequate room to travel to the left of a turning vehicle until much closer. This is not a site that would be considered to be a high traffic volume area, yet three other rear end collisions under similar circumstances have occurred at this site in the past nine years, and so the road layout may at least be a partial contributor to their occurrence. As noted earlier (Section 3.4.1 'Distraction'), the driver of the striking vehicle was also distracted prior to the collision by an open street directory held by the left front seat passenger.

Crash M152:

The collision occurred on a single lane local road immediately beyond a rough, slightly raised railway crossing. The driver of the striking vehicle stated that he was aware of the presence of another vehicle several car lengths ahead. The lead vehicle was travelling forward within the speed limit at last sighting. The driver of the striking vehicle moved to the left side of the roadway as he attempted to avoid the roughest area of a railway crossing, losing sight of the other vehicle in the manoeuvre. On travelling over the crossing, the driver was immediately confronted with the lead vehicle that was now stationary at a T-junction, its driver waiting to execute a right hand turn. The T-junction is situated twelve metres beyond the crossing. The driver of the striking vehicle braked but was unable to avoid colliding with the rear of the stationary vehicle. In addition to possible driver distraction (see Section 3.4.1), the combination of a sight restriction when avoiding the rough surface of the crossing, and the location of a T-junction so close to the crossing, increased the likelihood of a collision such as this. A map of the site for this crash is provided in Figure 3.4.

Crash M256:

Although an unsecured load and the presence of a stationary vehicle in the left lane were the primary causal factors in this crash (see Sections 3.4.1 'Distraction' and 3.4.5 'Unexpected events on the road'), it was made more likely by the presence of a left hand bend characterised by restricted vision. Roadside trees in close proximity to the carriageway compromised sight distance around the bend (see Figure 3.5). Had the trees not been present, the drivers of vehicles negotiating the bend would have had earlier warning of the stationary vehicle and possibly the unsecured load.

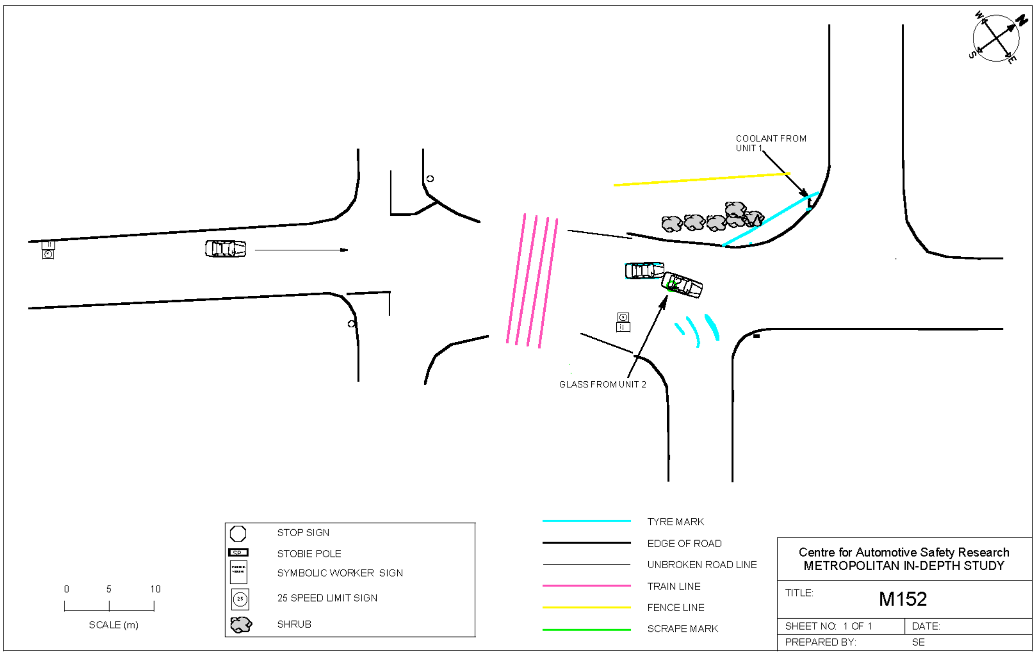

Figure 3.4
Plan of the crash site for M152

3.5 Summary

A sample of 38 rear end collisions has been investigated by CASR staff as part of the metropolitan in-depth crash investigation study. In each case, detailed information was collected about the vehicles, drivers, roads and other characteristics of the crash. This enabled a better understanding of the factors contributing to the causation of rear end crashes in Adelaide, South Australia. The rear end crashes investigated were typical of rear end crashes in general, as they mostly occurred on straight level roads in good weather on weekdays (see Section 2). Also, typically for rear end crashes, levels of injury were low. Of interest was the greater likelihood of hospital treatment being required for the occupants of struck vehicles rather than for those of striking vehicles.

The factor contributing most commonly to rear end collisions was the inadequate division of attention. This inadequate division of attention, referred to in mass data sets as 'inattention', took a number of different forms. It included cases in which drivers were not sufficiently focused on the driving task, cases in which drivers were distracted from the driving task by objects or events either in or outside the vehicle, cases in which the drivers were unable to adequately divide their attention between two or more driving-related tasks, and cases in which drivers were unable to adequately allocate their attention to appropriate aspects of the road and traffic environment when changing lanes. There were a number of additional cases in which some form of inadequate allocation of attention was suspected but the inability in these cases to interview the driver of the striking vehicle meant that it was not possible to confirm this suspicion.

Figure 3.5
Left hand bend prior to crash site for M256

Eleven of the 38 crashes involved a vehicle that was waiting to turn right. This suggests that rear end collisions occur often because of insufficient protection of right turning vehicles.

Indeed, there were four cases in which a right turning vehicle was struck on a major arterial road without a designated right turn lane and another crash in which a designated right turn lane was provided but was not of sufficient length to accommodate all of the vehicles waiting to turn right at the time of the crash. In the latter case, the vehicle was forced to remain stationary while protruding into a through lane, with the driver waiting for space to become available in the designated right turn lane. Another four crashes occurred in which a vehicle was struck when waiting to turn right from a single lane road, with insufficient room for the striking vehicle to pass the turning vehicle on the left.

Other factors found to contribute to rear end collisions were health problems of drivers, unexpected events (e.g. dog on the road), and congestion or restriction of possible vehicle movements created by legally parked vehicles. There were also three cases in which vision of the road ahead was restricted in some way, twice by a bend in the road and once by a railway crossing.

It is also important to note that a number of crashes featured a combination of contributing factors. As with other types of crash, rear end collisions are often multi-determined events, with a combination of driver and road environment factors leading to the crash. This means that successfully addressing any of the contributory factors would reduce crash numbers associated with other factors. For example, better protection of right turning vehicles would be expected to reduce the number of crashes associated with inadequate allocation of attention.

4 Literature review

Rear end crashes are known to be very common throughout highly motorised countries (Andreassen et al., 1996; Kodaka, Otable, Urai, & Koike, 2003; Shinar, 2000), and this has been reinforced by the analysis of crashes in South Australia presented in Section 2 of this report. Given the high likelihood of rear end crashes causing costly whiplash injuries (Navin, Zein, & Felipe, 2000; van Kampen, 2000), it would be useful to identify countermeasures with a high likelihood of reducing the frequency and severity of such crashes. Possible countermeasures for rear end crashes either require changes to roads, such as pavement skid resistance treatments, or changes to vehicles, such as collision avoidance systems. Literature concerned with these countermeasures is described and discussed in the remainder of the section.

4.1 Road-based countermeasures

Road-based countermeasures can be used to reduce the frequency and severity of rear end crashes in two different ways. The main broad type of road-based measure is the type that is aimed at reducing the likelihood that a driver in a following vehicle perceives too late that it is necessary to brake in order to avoid a collision with a lead vehicle. Countermeasures of this type include changes to signage, signals, road alignment, and lane configuration. The other type of countermeasure is one that aims to reduce the likelihood of late braking being insufficient to stop two vehicles colliding. The main method of achieving this is the use of skid resistant pavements.

4.1.1 Road design

As rear end collisions occur commonly at intersections (Andreassen et al., 1996; Wang, Ieda, & Mannering, 2003, and see Section 2 of this report), substantial effort has been expended in devising road infrastructure treatments likely to reduce rear end collisions at intersections. Intersection infrastructure problems that increase the likelihood of rear end collisions are mostly related to either (a) intersection designs that increase the likelihood of the presence of stationary vehicles whose drivers are waiting to turn into an intersecting road, or to (b) situations in which there is a high likelihood of the drivers of approaching vehicles being unaware of stationary traffic queued at the intersection. There are a number of road infrastructure treatments available for these problems.

The risk of rear end collisions at intersections can be increased by the presence of stationary vehicles waiting to turn either left or right. If there are excessive rear end collisions involving vehicles waiting to turn right, it may be that infrastructure at the intersection is insufficient to cope with the volume of right-turning traffic. Solutions to this problem include relocating the right turn to a different intersection, providing a right turn only lane, increasing the storage capacity of the right turn lane so that turning vehicles are not forced to queue in adjacent through lanes, and increasing the duration of right turn arrows. It may also be necessary to avoid situations in which vehicles wait in a through lane just beyond an intersection in order to turn right into a side road (Andreassen et al., 1996).

For left turning traffic, rear end collisions can be reduced by either making the left turn manoeuvre easier, or by slowing traffic approaching the intersection in the left turn lane. The former can be achieved by providing slip lanes on the road into which the left turning traffic can turn, prior to merging with traffic on the intersecting road (suitable for high volume left turn sites) (Aitken, Milvydas, & Barton, 1987). If this is not possible, then a large angle should be used for the entry of the left turning vehicle into the intersecting road, which will improve visibility of the traffic into which the turning vehicle must merge and, thus, aid appropriate gap selection (Aitken et al., 1987; Wang et al., 2003). The speed of approaching left turning vehicles can be reduced by realignment of the left turn slip lane (Andreassen et al., 1996).

The other main problem at intersections that leads to rear end collisions occurs when drivers are not prepared for stationary traffic that is queued at the intersection. One factor that may cause such a situation is restricted visibility of the intersection on an approaching road. Such restrictions to visibility can be caused by either vertical (i.e. crests) or horizontal curves prior to the intersection (Andreassen et al., 1996; Wang et al., 2003). Restrictions to visibility of intersections can be avoided in the road planning stage by not placing traffic signals or intersections directly after horizontal or vertical curves. Where an intersection is already in place, rear end collisions can be reduced by placing signs on the approach to the intersection, warning drivers in advance of the possibility of queued stationary traffic. For intersections where this is a regular problem, permanent signs may be appropriate, but variable message signs are also an option (Andreassen et al., 1996). The use of variable message signs could also aid in reducing the likelihood of rear end collisions at the scene of roadworks. On freeways or highways, vehicles are travelling at high speed and drivers are not expecting queued stationary traffic, as can occur at roadworks. For this reason, there is value in using variable message signs preceding the roadworks, warning of queued traffic. The placement of these warning signs is crucial, however. It is important that the message signs are not placed at a distance prior to the roadworks which could be exceeded by the length of the traffic queue but it is also important that the sign not be placed so far prior to the roadworks that the message loses its relevance for the motorists at whom it is directed (National Transportation Safety Board, 2001).

At intersections, it may not be a visual obstruction that causes problems, but low traffic signal visibility. Means of increasing traffic signal visibility include putting signal heads on a mast arm, using larger lenses, and using a greater number of signal heads. The latter countermeasure decreases the likelihood that traffic signals at an intersection will fall outside a driver's central field of view or be obscured by a large vehicle in an adjacent lane (Ogden (1996) in Navin et al., 2000). A study in Canada of changes in crash occurrence at signalised intersections after the addition of a second primary traffic signal head found cost-effective reductions in crashes overall, with the greatest crash reductions being for rear end collisions (Navin et al., 2000).

Another means of reducing the risk of rear end collisions at intersections is the introduction of clearway and parking restrictions on approaches to intersections. This will enhance visibility of the intersection and other traffic, and also reduce obstacles in the vicinity of the intersection that could cause vehicles to stop (Ogden (1996) in Navin et al., 2000).

Pedestrians crossing when not expected by drivers may also be a problem. If the nature of the problem is poor conspicuity of the pedestrian crossing, then additional lighting and the provision of warning signs may be useful (Ogden (1996) in Navin et al., 2000). If the problem is pedestrians crossing illegally, then the use of fences on the median could be used to discourage this behaviour (Wang et al., 2003).

Other situations that increase the likelihood of rear end crashes are lane drops where visibility is restricted, particularly lane drops at the other side of an intersection, and freeway on-ramps and off-ramps being in close proximity to one another. The latter results in rear end collisions because it leads to drivers changing lanes and braking in front of one another, which, in turn, leads to chain reactions of braking back through the freeway traffic. The problem of ramps being too close to one another can also be exacerbated by sight distance restrictions (Andreassen et al., 1996).

4.1.2 Pavement skid resistance

Even if appropriate traffic engineering is adopted to reduce rear end collision occurrence, the tendency for drivers to get distracted or be inattentive when driving always poses the possibility that drivers will fail to detect early enough that traffic ahead is stationary or travelling slowly, leading, in turn, to late braking. However, the use of higher skid resistant pavements can increase the likelihood that such late braking will still be sufficient to avoid a rear end collision.

Cairney (1997) reviewed the literature concerned with skid resistance and road crashes. The most important finding of the review was that before and after comparisons of roads resurfaced with skid resistant material typically found significant reductions in wet weather crashes. Although results were mixed for dry weather crashes, the reductions in wet weather crashes were sufficient in magnitude to make the surface treatments cost-beneficial.

However, to achieve desirable cost-benefit ratios, it is best if skid resistant resurfacing is targeted at appropriate road sites, rather than applied everywhere. Holbrook (1977) compared the likely benefits of two different road treatment strategies in Michigan, USA and found that it was better to resurface roads in a way likely to prevent the most wet weather crashes (taking into account local levels of rain and crash history) than to keep skid resistance at an acceptable level throughout the entire road network. The latter would be less effective and would be expensive. Cairney (1997) advised that locations appropriate for skid resistant pavement treatment were those that have a high ratio of wet to dry weather crashes, and that have either high crash rates or a high total number of crashes (or both). Choosing roads on the basis of crash history eliminates the need for time-consuming skid resistance measurement procedures. Also, sites which are characterised by the need for frequent braking (e.g. those with a steep grade) would be more likely to benefit from skid resistant paving. Finally, if a road is characterised by rapidly increasing traffic growth or is already unable to cope with the level of traffic it supports, then long term surface treatments are not justified, as significant structural changes to the road will soon be necessary (Cairney, 1997).

4.2 Vehicle-based countermeasures

Well-designed road environments that conform to the recommendations of the previous section (4.1) would be expected to reduce the incidence of rear end collisions but such crashes occur throughout the road network, not just at “blackspots”. Therefore, countermeasures additional to road improvements are necessary. The countermeasures applied to vehicles that could reduce rear end collision incidence are either directed at increasing the conspicuity of braking vehicles, or alerting the driver of the following vehicle that braking is necessary to avoid a collision with a vehicle in front.

4.2.1 Vehicle conspicuity

Altering the conspicuity of the rear of vehicles is thought to be a useful countermeasure because low conspicuity has been hypothesised to play a role in rear end collisions. Sullivan and Flannagan (2003) looked at changes in rear end collision occurrence in the weeks prior to, and following, a change in ambient illumination caused by daylight saving changeovers in the United States. Such analyses are used to compare the effects of changes in ambient illumination while keeping clock time, and hence driving habits, constant. Using 15 years of fatal crash data, they found that the risk of rear end collisions in hours of darkness was over double that in hours of daylight. In particular, trucks were eight times more likely to be rear-ended in hours of darkness. The authors concluded that their findings were indicative of an increased rear end crash risk resulting from reduced conspicuity of vehicles at night (Sullivan & Flannagan, 2003).

One means of increasing vehicle conspicuity is the application of retro-reflective material to the rear of vehicles. Morgan (2001) conducted a study to determine the effectiveness of red and white retroreflective tape for reducing side and rear impacts with heavy trailers (those weighing over 10,000 pounds, or approximately 4,500 kilograms). The application of such tape became compulsory in the United States for all new trailers manufactured after 1993. It was thought that trailers are often not visible at night to other drivers until they are dangerously close, and so adding retroreflective tape would indicate to following drivers that a trailer was ahead. It was also hypothesised to aid drivers in judgement of distance and rate of approach. Morgan collected data on over 10,000 crashes involving heavy trailers and analysed crash involvement according to the presence of retroreflective tape, the level of ambient illumination, and crash type. It was found that retroreflective tape reduced the occurrence of side and rear impacts with trailers by over 40 percent at night on roads without artificial lighting. The tape was especially effective on flatbed trailers, which presumably would be more difficult to see than other trailers without the enhanced conspicuity provided by the tape. Also, larger reductions were found for injury crashes and those in which the trailer was struck by drivers under the age of 50 (Morgan, 2001). The requirements in Australia are not as stringent as those in the USA. Although Australian Design Rule 13 requires heavy trailers (gross mass over 10 tonnes) to have retroreflective marker plates on the rear, they are not required to extend the full width of the trailer. Also, retroreflective marker plates are not required for smaller trailers.

Another change to the rear of vehicles that has been shown to be effective in reducing crashes is the addition of Centre High Mounted Stop Lamps (CHMSLs). These additional brake lights, usually mounted in the rear window, not only provide an additional light to warn following drivers of braking but also, due to their position, are visible through a number of following vehicles. The information that vehicles further ahead are braking effectively provides drivers with advanced warning of the possibility that the vehicle directly in front of them is likely to brake. Early reports of the effectiveness of CHMSLs (Kahane, 1987, 1989) indicated reductions of around 20 percent in rear end collisions in which the front vehicle was braking but later studies found more modest reductions. Farmer (1996) compared vehicles of the model year 1985 with those of 1986 (the first full year in which CHMSLs were required in the USA) for a period of six years (1986 to 1991) using insurance crash data. After adjusting for differences in vehicle ages, a rear end crash reduction of 5 percent was found for the vehicle models fitted with CHMSLs (Farmer, 1996). This analysis was not able, however, to provide an indication of the extent to which CHMSLs, by providing advance warnings of braking further down the traffic stream, reduced the likelihood that vehicles following them were struck from behind. In Australia, CHMSLs have been fitted to all new cars since 1989, in compliance with Australian Design Rule 60. Andreassen et al. (1996, p53) recommended that retro-fitting of CHMSLs to vehicles manufactured prior to 1989 be "encouraged" and that CHMSLs be fitted to all new passenger vehicles, including panel vans and utility vehicles. Given that vehicles manufactured prior to 1989 are now over 15 years old and are disappearing from the vehicle fleet, the possible gains from retrofitting CHMSLs are considerably smaller than they would have been when Andreassen et al. made this recommendation.

Another recent study was conducted to determine whether any benefits were likely from another alteration to vehicle brake lights (Shinar, 2000). This study looked at the crash involvement of a fleet of government vehicles, half of which were fitted with an advanced brake warning system, which activated the brake lights whenever the accelerator was released rapidly (a minimum of 0.3 metres per second). The theory behind the system is that such rapid disengagement of the accelerator is typically followed by braking, and so earlier activation of the brake lights would give drivers in following vehicles an average of 0.25 seconds of extra warning of the need to brake. In the study, the odds of "relevant" rear end collisions were calculated for the two sets of cars (those with and those without the advanced brake warning system). Relevant rear end collisions were those in which the vehicle was struck from behind by an attentive driver after abrupt braking. Crashes in which the vehicle was stationary prior to the impact were excluded. No significant difference was found between the two sets of vehicles in the odds that they would be involved in a relevant rear end collision. It was concluded by the authors that, if the warning system has an effect, it is a small one, and so the system is not likely to be a cost-effective device for reducing rear end crash occurrence (Shinar, 2000).

4.2.2 Collision avoidance systems

As noted by Mortimer (1993), drivers do not immediately brake upon seeing the activation of brake lights on a vehicle in front of them. They use the brake signal on vehicles ahead only as a signal of the *possibility* of needing to brake. Whether or not they do brake is decided on the basis of their perceptions of the necessity of braking to avoid colliding with the vehicle in front. These decisions require consideration of the distance to the vehicle in front and the rate of closure between the two vehicles. Studies of drivers' perceptual processes have found that judgements about the rate of closure between a driver's own vehicle and the one in front are based largely on the visual angle of the leading vehicle. As a result of this, drivers do not perceive relative velocity cues until there is only a short time and distance to the vehicle in front, which, in turn, is likely to contribute to the occurrence of rear end collisions (McGehee, Dingus, & Horowitz, 1992; Mortimer, 1990).

Given this limited capacity of drivers to make accurate judgements on relative velocities based on visual cues, a number of intelligent transport systems have been designed to aid the drivers in avoiding rear end collisions. There are two main types of such systems. One is 'adaptive cruise control', which detects slower moving vehicles ahead and automatically, through deceleration and braking, adjusts the speed of the 'host' vehicle to a comparable level. The other type is a 'collision warning system', which detects slower vehicles ahead and warns the driver of the host vehicle so that he or she can then take appropriate action (National Transportation Safety Board, 2001). Most recent research has been focused on the effectiveness of the combination of the two systems. That is, investigations have been conducted into the crash avoidance properties of systems in which the vehicle reduces its speed in response to slowing vehicles ahead by releasing the accelerator and lightly braking, but, in situations requiring heavier braking to avoid a collision, warns the driver that further action is necessary. Evaluations of prototypes of these devices have been conducted using complex mathematical and computer modelling, driving simulator experiments, and field trials in fleet vehicles being driven on public roads.

There are a number of issues in need of resolution with regard to the successful implementation of adaptive cruise control and collision warning systems. One of the most important is the timing of warnings given to the driver to brake in order to avoid a collision. If warnings are given too early, there will be too many false alarms and drivers will begin to disregard the system (Kodaka et al., 2003; Lee, McGehee, Brown, & Reyes, 2002). As Horowitz and Dingus (1992) noted, the typical driver probably has a rear end collision once every 25 years and so warnings should ideally be rare. However, if the system is set so that warnings are given too late, then the system will be ineffective because it will not give drivers sufficient time to avoid a collision (Kodaka et al., 2003; Lee et al., 2002).

One study that directly addressed the issue of the timing of warnings given to drivers was that conducted by Lee et al. (2002). This study compared rear end collision avoidance on a simulator according to drivers receiving an early or late warning, or no warning at all, and according to whether the drivers were distracted or not by a secondary task. Different speeds, headways, and lead vehicle deceleration rates were employed in order to investigate the warning timing over a range of conditions. The system being tested used a combination of auditory warning tones and the appearance of crash icons on the instrument panel, and worked on the basis of an algorithm combining information on distance to the vehicle in front, the assumed driver reaction time to a warning and deceleration capability of the vehicle. The early warning condition involved the system acting as though the vehicle was capable of 0.4G deceleration, while the late warning condition was based on a 0.75G deceleration capability. The other two parameters were kept constant. It was found that early warnings were associated with the least number of crashes on the simulator, followed by late warnings and no warnings. This reduction in crashes was found to be due to faster reaction to the lead vehicle braking (assessed by measuring release of the accelerator). Drivers receiving no warning of the deceleration of the vehicle ahead were forced to brake more heavily than drivers receiving the early warning. Therefore, an early warning protects the driver from colliding with the vehicle in front but also means less need for heavy braking, and so may reduce the likelihood of being struck from behind. The fact that the early warning was associated with milder braking than for conditions in which the driver reacted later demonstrates that drivers modulate their braking response according to the evolving situation. The warning is therefore mainly a cue to release the accelerator and attend to the vehicle in front, rather than immediately triggering a strong braking response. This pattern of results was the same in the distraction and no distraction conditions. Furthermore, the warnings conditions (early, late, none) had a greater effect on crash involvement rates than did levels of distraction. The authors acknowledged that the results of simulator studies must be treated with caution because the threat of collisions is not a real one, and also that the study did not evaluate the effects of false alarms on the success of the warning system. However, they argued that since the system was found to influence driver's attention rather than to lead to immediate braking, the system would be unlikely to lead to unnecessary braking and so the safety benefits would outweigh any negatives (Lee et al., 2002).

As mentioned above, in assessments of collision warning systems, it is important to consider not just the likelihood of a collision with a vehicle in front but also any effects of the system on following vehicles. Touran, Brackstone and McDonald (1999) conducted a modelling study of an adaptive cruise control and rear end collision warning system, in which they considered its effects on the likelihood of the equipped vehicle striking the one in front and the likelihood of it being struck from behind, or of other rear end collisions occurring further back in the traffic stream. The device assessed in this study maintained a target headway of 1.4s and when braking capabilities of the device were insufficient to avoid a collision, the driver was warned that intervention was necessary. Models were developed of the braking profiles of four vehicles travelling on a highway, with the second vehicle being equipped with the device and responding to heavy braking of the front vehicle. The outputs of this model, in terms of crash involvement probabilities, were compared to the outputs of the same models, except with no device fitted to the second vehicle. Various parameters (e.g. level of braking by the front vehicle, driver perception reaction time) were varied and 5,000 iterations were run. It was concluded that the probability of the second vehicle striking the first was decreased by the addition of the device but that there was an increased likelihood of the third vehicle striking the second, in cases of heavy braking of the front vehicle, and an increased likelihood of the fourth vehicle striking the third at all levels of braking. It was concluded that equipping a car with the device could "significantly reduce the probability of the collision with the car ahead" but that it "may adversely affect the situation for the following cars" (Touran et al., 1999, p567). The authors noted that the actual outcomes of use of the device could be affected by changes in driver behaviour (attentiveness, response time, driving speed) as a result of knowing the device was fitted, by the ability of the device to function in adverse weather conditions, by the level of occurrence of false alarms, by the ability of drivers to see several cars in front of the one they are following, by drivers adopting much smaller headways than the 1.4s used in the models, and by the likelihood that drivers will switch off the device (Touran et al., 1999).

As suggested by this list of factors that could affect the usefulness of collision avoidance systems, the most convincing assessment of intelligent transport systems technology comes from field tests of vehicles equipped with the technology. Only field tests can reveal the real world interactions between drivers and the technology, and the likely benefits or otherwise of fitting the technology to the vehicle fleet. Regan et al. (2004) reported on the preliminary findings of a field study of a car fitted with a number of intelligent transport systems, including a following distance warning device. This device gave the driver visual warnings at headways below 2.0s, with the warnings increasing in intensity with decreasing headway until an auditory warning is added at headways of less than 1.1s. In the study, a fleet of government vehicles was used and the various devices were switched on and off throughout the trial so that driving behaviour before, during and after exposure to the devices could be examined. Preliminary results indicate that the following distance warning device reduced the percentage of time people drove at small headways but this change in behaviour disappeared after the device was switched off (Regan et al., 2004).

A field test of adaptive cruise control and a forward collision warning system was conducted by Kiefer, Salinger and Ference (2005). Thirteen vehicles were fitted with these systems and driven for four weeks. During the first week, the devices were not activated and baseline driving behaviour data were collected. The adaptive cruise control could apply brakes at a level of 0.3G and the desired headway (ranging from one to two seconds) was chosen by the driver. The forward collision warnings consisted of visual icons of different colour according to the urgency of the situation, starting at green, then amber, then red. The final warning involved a flashing red icon and a beeping sound. It was found that both devices reduced tailgating and neither appeared to have unintended negative safety consequences. Adaptive cruise control also resulted in fewer overtaking manoeuvres, and any overtaking manoeuvres were made at greater headways. The maximum braking level possible for the adaptive cruise control was rarely necessary, as drivers would usually intervene themselves when adaptive cruise control began working. Forward collision warnings were more common when the adaptive cruise control was not operating. One problem found with the forward collision warning system was the common occurrence of alerts in response to stationary roadside objects outside of the vehicle path. It was concluded that the development of an acceptable forward collision warning system represented a "formidable technical challenge" (Kiefer et al., 2005, p14).

Intelligent transport systems are a relatively new endeavour in road safety and improvements to designs are ongoing. Collision warning systems suitable for rear end collision avoidance are rapidly developing in complexity. Kodaka et al. (2003) reported on a device that uses a radar sensor for forward vehicle detection that can function well in bad weather, can detect vehicles ahead on curves and at distances of 100m. The vehicle is also equipped with a wheel speed sensor, yaw rate sensor and steering angle sensor, so that the system cam calculate the likelihood of a collision and whether a potential collision is best avoided with a steering or braking response (Kodaka et al., 2003). The National Highway Traffic Safety Administration and General Motors are collaborating on a system that uses forward looking radar, a forward vision camera, a GPS receiver coupled with a map database, and various in-vehicle sensors, so that it can detect and track targets and lane boundaries, and predict upcoming road geometry. These assorted data are 'fused' to determine if vehicles or objects ahead are in the path of the vehicle and whether a collision is likely if no action is taken by the driver. It can track 15 targets simultaneously, and is capable of recognising trucks in adjacent lanes on curves, and vehicles slowing to turn off a highway, as not posing a collision threat (Ferenc, 2001; Koopmann & Najm, 2003).

Cohn (2002), meanwhile, conceived of a collision avoidance system that, instead of warning the driver of the host vehicle that he or she is too close to the vehicle in front, warns the drivers of following vehicles that they are approaching too quickly. This system, suitable for large vehicles like trucks and buses, incorporates radar equipment to detect close following or rapidly approaching vehicles and a series of amber lights that warn the following driver of the high risk of collision. In a laboratory study, Cohn found that if an array of lights lit up sequentially, the reaction time of following drivers would be shorter than if the lights lit up all at once (Cohn, 2002). Field tests of Cohn's light were conducted (Burns, 2005), with assessments made of the degree to which the warning lights changed the braking behaviour of drivers of cars behind buses. This was done by measuring the braking profiles of samples of following vehicles, with and without activation of the light. Even without any education of the public regarding the lights, the field test revealed that drivers exposed to the warning lights had lower levels of braking intensity behind the bus. This was due to their attention being drawn to the bus by the warning lights, and occurred regardless of which of three different algorithms were used to determine the circumstances in which the lights were triggered. Further development, particularly of the sensors used to monitor approaching vehicles and trigger the warning lights, is needed before the system is able to be commercialised (Burns, 2005).

Such innovations as those being developed by intelligent transport systems engineers need to not only provide a demonstrable safety benefit but also have to appeal to consumers and be user-friendly. In Japan, there has been little take-up of adaptive cruise control because few drivers use expressways, and even conventional cruise control has been removed from vehicles because of a lack of interest from drivers (National Transportation Safety Board, 2001). Mitsopoulos, Regan and Haworth (2002) conducted a focus group of drivers in Victoria to determine the factors involved in likely consumer acceptance of intelligent transport systems. With regard to forward collision warning devices, participants claimed that cost and proven effectiveness would be the most important determinants of whether they would be interested in buying cars equipped with the devices. Concerns were raised about whether there would be repetitive nuisance warnings in dense traffic, whether people may get overly reliant on the system, whether an audio warning could be heard over the radio, and whether it would be difficult to discriminate between different warnings if a number of different systems were fitted to the car (Mitsopoulos et al., 2002). As noted earlier, a field test was conducted by Kiefer et al. (2005) of a system incorporating adaptive cruise control and forward collision warnings. Interviews with the drivers after the field test found consumer appeal for the adaptive cruise control but not for the forward collision warnings. This was attributed to the appeal of reduced workload and stress provided by adaptive cruise control, and to the common occurrence of nuisance forward collision warnings given for stationary roadside objects not in the vehicle path (Kiefer et al., 2005). Finally, a report by the National Transportation Safety Board in the United States also notes that it would be desirable if there was uniformity across the systems provided by different vehicle manufacturers, particularly with respect to the human interface (National Transportation Safety Board, 2001).

4.3 Summary and conclusions

Rear end collisions are a common crash type, and are typically associated with neck injuries and costly compulsory third party claims. Causes of rear end collisions include certain design characteristics of roads (particularly at intersections) and, most commonly, driver distraction or inattention. Therefore, to reduce the incidence of rear end collisions, such road design characteristics can be treated and methods to alert drivers to the risk of collision can be implemented. Alerting drivers to the risk of collision, due to following too closely or rapidly approaching a stationary or slow vehicle, can be accomplished with increased conspicuity of the rear of vehicles, and with the introduction of intelligent transport systems such as adaptive cruise control and advanced collision warning systems. Intelligent transport systems are currently being developed, improved and evaluated in a number of ongoing projects, the outcomes of which remain to be seen. Although these devices are capable of providing early warning of potential collisions, it is necessary to examine the way drivers interact with them in real-world settings before being certain that they can provide cost-effective reductions in levels of crash involvement. Another means of reducing rear end collisions, mainly in wet weather, is the improvement of pavement skid resistance. To be cost-effective, such skid resistance treatments should be reserved for roads with a high rate or number of such crashes, rather than implemented system wide.

5 Overall summary and conclusions

Due to the common occurrence of rear end collisions in South Australia, and the costliness of CTP claims associated with them, a study was undertaken into the nature of, and possible countermeasures for, rear end collisions. This study included an analysis of five years of police-reported crash data, an analysis of a sample of rear end crashes investigated as part of the CASR metropolitan in-depth crash study, and a literature review concerned with countermeasures for rear end crashes.

The results of the mass crash data analysis and the in-depth crash investigation were consistent, with most rear end crashes occurring on straight, level roads and in clear weather conditions. Both analyses also revealed that drivers of striking vehicles were more likely to be young and male than drivers of the vehicles they struck. This is consistent with notions that young, male drivers represent a problematic group of drivers who are often crash-involved and also tend to be responsible for their crashes. Rear end crashes, in this respect, are typical of crashes in general. Injuries resulting from rear end crashes also tended to be of low severity, and the in-depth study revealed that occupants of struck vehicles were more likely to require hospital treatment than occupants of striking vehicles.

Factors that increase the likelihood of the occurrence of rear end collisions include higher traffic density (peak hour traffic, arterial roads), the presence of intersections, and the presence of right turning vehicles. These factors are related to rear end crashes because they increase the likelihood of conflict with slowing or stationary vehicles on the road.

There are a number of countermeasures to reduce rear end crashes involving stationary, right turning vehicles. Where intersections feature a high frequency of collisions with right turning vehicles, possible countermeasures include: relocation of the right turn to a different intersection, provision of a right turn only lane, increasing the storage capacity of the right turn lane so that turning vehicles are not forced to queue in adjacent through lanes, and increasing the duration of right turn arrows. It may also be necessary to prevent situations in which vehicles wait in a through lane just beyond the intersection in order to turn right into a side road. The sample of rear end crashes investigated in the in-depth study included cases in which vehicles were waiting to turn right from arterial roads without the benefit of designated right turn only lanes, and also included a case in which the capacity of the right turn lane was insufficient to cope with the number of vehicles waiting to turn right, resulting in a vehicle protruding into the through lane and being struck in the rear. There were also a number of crashes in which vehicles were struck when waiting to turn right from single lane roads that did not allow through traffic to pass on the left. For the latter crashes, available engineering solutions are likely to be prohibitively expensive, unless traffic volumes satisfy the requirements for a major upgrade of the road, as was the case for the road in one of the crashes investigated. Such crashes may need to be addressed using countermeasures for inadequate allocation of attention (see below).

Countermeasures are also available for left turning traffic at intersections. Slip lanes that make turning simpler can be introduced, enabling left turning traffic to turn into the adjoining road prior to merging with traffic, or a larger angle between the left turn lane and adjoining road can be used, enabling better visibility of traffic to aid the determination of gap acceptance. There was one crash in the in-depth study involving a left turning vehicle being struck from behind. The striking driver moved in response to a gap in the traffic on the adjoining road in anticipation of the struck vehicle turning. If the left turn had been simpler, the struck vehicle may have been able to turn at this point rather than remaining stationary, although inadequate allocation of attention on the part of the striking driver was still the prime determining factor of the crash.

Another factor that can increase the likelihood of rear end collisions is parked vehicles by the side of the road. Clearways and parking restrictions on the approach to intersections are useful because they enhance the visibility of the intersection and other traffic, and reduce obstacles in the vicinity of the intersection that could cause vehicles to stop. The in-depth study included three cases where legally parked vehicles may have contributed to the occurrence of a rear end collision. It is also important to note that both the TARS analysis and the in-depth study analysis excluded cases where the struck vehicle was parked. In the in-depth study, seven of the original sample of 47 cases classified as rear end crashes involved collisions into the rear of parked vehicles.

Relatively few rear end collisions in the in-depth study were the result of the restriction of driver vision caused by curved roads. This is consistent with the small percentage of such crashes that occur on curved roads, due to the paucity of curved roads in metropolitan Adelaide. Nonetheless, the literature suggests that where intersections are present shortly after a curve in the road, it would be useful for drivers to be warned by appropriate signs of the possibility of queued stationary traffic following the curve.

Also, relatively few rear end crashes in the in-depth study were associated with wet weather, as was the case with the police-reported crashes included in the TARS analysis. This would suggest that relatively few of the crashes would have been avoided, or their severity reduced, by skid resistance treatment of the road surface. Skid resistance treatments, however, may still prove cost-beneficial in South Australia if applied to roads with high crash rates, especially if such roads have a high ratio of wet to dry weather crashes or are characterised by a marked down slope.

Turning to driver-related factors, inadequate allocation of attention was a frequent contributor to crash causation, and may have been underestimated in the results, given that interviews in which attentional issues were explored were not possible with all crash participants. Inadequate allocation of attention could be divided into four different types: cases in which drivers were not sufficiently focused on the driving task, cases in which drivers were distracted from the driving task by objects or events either in or outside the vehicle, cases in which the drivers were unable to adequately divide their attention between two or more driving-related tasks, and cases in which drivers were unable to adequately allocate their attention to appropriate aspects of the road and traffic environment when changing lanes.

In order to combat the inadequate allocation of attention of drivers, the necessary countermeasure would be the installation in vehicles of collision avoidance systems. Such systems typically combine adaptive cruise control, which slows the vehicle automatically in response to the presence of slower vehicles ahead, and devices that actively alert the driver to the need to apply heavier braking to avoid a collision. Early studies of prototype collision avoidance systems have revealed that they are capable of providing useful early warnings to drivers of the need to take evasive action to avoid collisions. However, it is necessary to examine the way drivers interact with them in real-world settings before being certain that they can provide cost-effective reductions in levels of crash involvement. Specifically, it needs to be assessed whether drivers begin to disregard the collision warnings after a series of 'nuisance' alarms.

The literature also reports on the advantages of increasing the conspicuity of the rear of vehicles to decrease the likelihood of rear end collisions. Few crashes in the in-depth study were attended at night, and none of those occurring during the day was clearly related to low conspicuity of the rear of the struck vehicle. Although this may mean that low conspicuity is not a common factor in rear end crashes, there are likely to be some such crashes in which it is. The use of specially designed lights on the rear of vehicles to warn following drivers that they are too close or closing too quickly may prove useful, by both increasing conspicuity and combating the inattention of following drivers, although work on these projects is in the early stages only.

Finally, a number of the rear end collisions investigated in the in-depth study were associated with medical conditions and/or drug use on the part of the driver of the striking vehicle. Although these crashes also involved inadequate allocation of attention to the driving task, it is unclear whether collision avoidance systems would have been sufficient to prevent their occurrence. These cases highlight the importance of the application of medical fitness to drive guidelines (Austroads, 2001) to prevent people driving when their mental or physical state is incompatible with the safe operation of a motor vehicle.

In summary, this report has provided a detailed account of the nature of rear end collisions, using both mass police-reported crash data and the information collected in in-depth metropolitan crash investigations. The most common factors contributing to these types of crashes are the lack of protection for right turning vehicles and the inadequate allocation of attention by drivers to the driving task. Countermeasures are available for both of these contributing factors. Also, although not directly addressed in this report, it needs to be borne in mind that countermeasures that reduce traffic congestion would provide major reductions in rear end collisions.

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References

Aitken, R. N., Milvydas, A. J., & Barton, A. L. (1987). Left turn slip lane study. In New Zealand Roading Symposium 1987 Volume 3 (pp. 607-614). Wellington, New Zealand: New Zealand National Roads Board.

Andreassen, D., Bishop, J., Catchpole, J., Cusack, S., Morgan, R., Tan, H. W., et al. (1996). Study of Rear End Accidents: Final Report (Report No. RS 756-4). Vermont South, Victoria: ARRB Transport Research Ltd.

Australian Bureau of Statistics. (2005). Year Book Australia 2005. Canberra, ACT, Australia.

Austroads. (2001). Assessing fitness to drive: Guidelines and standards for health professionals in Australia (2nd ed.). Canberra: Austroads.

Burns, J. (2005). A rear end collision warning system for transit buses. Paper presented at ESV: 19th International Technical Conference on the Enhanced Safety of Vehicles, Washington DC.

Cairney, P. (1997). Skid resistance and crashes - A review of the literature (Report No. ARR 311). Vermont South, Victoria: ARRB Transport Research Ltd.

Cohn, T. (2002). On the back of the bus. Access, 21, 17-21.

Farmer, C. M. (1996). Effectiveness estimates for center high mounted stop lamps: A six year study. Accident Analysis and Prevention, 28(2), 201-208.

Ferenc, J. J. (2001). Rear-end collision warning system field operational test - Status report. Paper presented at ESV: 17th International Technical Conference on the Enhanced Safety of Vehicles.

Holbrook, L. F. (1977). Prediction of wet weather surface intersection accidents from weather and skid test data. Transportation Research Record, 623, 29-39.

Horowitz, A. D., & Dingus, T. A. (1992). Warning signal design: A key human factors issue in an in-vehicle front-to-rear end collision warning system. In Proceedings of the Human Factors Society 36th Annual General Meeting (pp. 1011-1013). Atlanta, Georgia, USA.

Kahane, C. J. (1987). The effectiveness of center high mounted stop lamps: A preliminary evaluation (Technical Report DOT-HS-807-076). Washington DC: US Department of Transportation, National Highway Traffic Safety Administration.

Kahane, C. J. (1989). An evaluation of center high mounted stop lamps based on 1987 data (Technical Report DOT-HS-807-442). Washington DC: US Department of Transportation, National Highway Traffic Safety Administration.

Kiefer, R. J., Sallinger, J., & Ferenc, J. J. (2005). Status of NHTSA's rear-end crash prevention research program. Paper presented at the ESV: 19th International Technical Conference on the Enhanced Safety of Vehicles, Washington DC.

Kodaka, K., Otable, M., Urai, Y., & Koike, H. (2003). Rear end collision velocity reduction system. In D. J. Holt (Ed.), Recent developments in automotive safety technology (pp. 273-281). Warrendale, Pennsylvania, USA: Society of Automotive Engineers.

Koopmann, J., & Najm, W. G. (2003). Characterising the capability of a rear end crash avoidance system. In D. J. Holt (Ed.), Recent developments in automotive safety technology (pp. 669-676). Warrendale, Pennsylvania, USA: Society of Automotive Engineers.

Lee, J. D., McGehee, D. V., Brown, T. L., & Reyes, M. L. (2002). Collision warning timing, driver distraction, and driver response to imminent rear-end collisions in a high-fidelity driving simulator. Human Factors, 44(2), 314-334.

McGehee, D. V., Dingus, T. A., & Horowitz, A. D. (1992). The potential value of a front-to-rear collision warning system based on factors of driver behaviour, visual perception and brake reaction time. In Proceedings of the Human Factors Society 36th Annual General Meeting (pp. 1003-1005). Atlanta, Georgia, USA.

MIMS Australia. (2005). MIMS. Crows Nest, NSW: MIMS Australia.

Mitsopoulos, E., Regan, M. A., & Haworth, N. (2002). Acceptability of in-vehicle intelligent transport systems to Victorian car drivers. Paper presented at the Road Safety Research, Policing and Education Conference, Adelaide, South Australia.

Morgan, C. (2001). The effectiveness of retroreflective tape on heavy trailers (Report No. DOT HS 809 222). Washington DC: US Department of Transportation, National Highway Traffic Safety Administration.

Mortimer, R. G. (1990). Perceptual factors in rear end crashes. In Proceedings of the Human Factors Society 34th Annual General Meeting (pp. 591-594). Orlando, Florida, USA.

Mortimer, R. G. (1993). The high mounted brake light: A cause without a theory. In Proceedings of the Human Factors Society 34th Annual General Meeting (pp. 955-959). Seattle, Washington, USA.

National Transportation Safety Board. (2001). Vehicle- and infrastructure-based technology for the prevention of rear end collisions (Report No. PB2001-917003). Washington DC: National Transportation Safety Board.

Navin, F., Zein, S., & Felipe, E. (2000). Road safety engineering: An effective tool in the fight against whiplash injuries. Accident Analysis and Prevention, 32(2), 271-275.

Regan, M. A., Young, K., Triggs, T., Tomasevic, N., Mitsopoulos, E., Tierney, P., et al. (2004). Driver adaptation to in-vehicle intelligent transport systems: Preliminary findings from the TAC SafeCar Project. Paper presented at the Road Safety Research, Policing and Education Conference, Perth, Western Australia.

Shinar, D. (2000). Fleet study evaluation of an advance brake warning system. Human Factors, 42(3), 482-489.

Sullivan, J. M., & Flannagan, M. J. (2003). Risk of fatal rear end collisions: Is there more to it than attention? Paper presented at the Second International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Utah, United States.

Touran, A., Brackstone, M. A., & McDonald, M. (1999). A collision model for safety evaluation of autonomous intelligent cruise control. Accident Analysis and Prevention, 31(5), 567-578.

van Kampen, B. (2000). Factors influencing the occurrence and outcome of car rear-end collisions - The problem of whiplash injury in the Netherlands. IATSS Research, 24(2), 43-52.

Wang, Y., Ieda, H., & Mannering, F. (2003). Estimating rear end accident probabilities at signalized intersections: Occurrence-mechanism approach. Journal of Transportation Engineering, 129(4), 377-384.

Williams, A. F., & Shabanova, V. I. (2003). Responsibility of drivers, by age and gender, for motor vehicle crash deaths. Journal of Safety Research, 34(5), 527-531.