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ACCIDENT RESEARCH CENTRE

REVIEW OF TRUCK SAFETY –

STAGE 2: UPDATE OF CRASH STATISTICS

by

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Abstract:

This report presents an updated statistical profile of the characteristics of heavy vehicle crashes in Victoria to provide a basis for estimating benefit:cost ratios (BCRs) for underrun protection.

Significant limitations exist in the availability, scope and timeliness of truck crash data, particularly for rigid trucks. Comparisons between truck crashes in Victoria and nationally showed that the number of fatal crashes appears to have increased Australia-wide and in Victoria since 1997. Fatality rates for articulated and rigid trucks (both in terms of registered vehicles and in terms of distance travelled) are lower in Victoria than Australia-wide. Australia-wide and in Victoria, fatality rates are higher for articulated than rigid trucks. Otherwise, the characteristics of fatal truck crashes in Victoria and the rest of Australia are generally similar.

From 1996-2000 in Victoria, about 40% of truck casualty crashes involved articulated trucks and 60% involved rigid trucks. Articulated truck crashes were more severe overall, and for truck occupants in particular. Car occupants were the largest group among those killed (64%) with 16% of those killed being truck occupants. Only 20% of crashes occurred at night but these crashes were generally more severe than daytime crashes. About three-quarters of the crashes occurred in metropolitan areas, although the proportion was lower for articulated than rigid truck crashes. The proportion of crashes resulting in death or serious injury increased with speed zone. For both articulated and rigid trucks, the largest number of fatal crashes involved vehicles travelling in opposing directions – 'head-on' crashes. Same direction crashes were the most common type of serious injury and other injury crash for both articulated and rigid trucks.

For all of the underrun protection measures included, the BCRs were higher for articulated trucks than rigid trucks. A package of front, side and rear underrun had a BCR of greater than 1 for both articulated trucks and rigid trucks, whether a 17- or 25- year lifetime is assumed. Not surprisingly, the BCR was doubled if the package cost $500, compared to if the package cost $1,000. The BCRs also exceeded 1 for each type of underrun protection – front (at a cost of either $100 or $200), side or rear – for both articulated trucks and rigid trucks; again regardless of the lifetime. The BCRs were considerably larger for front underrun protection than for side underrun protection, with the lowest BCRs found for rear underrun protection.

Key Words:
Safety, accident, injury, heavy vehicle, design, vehicle occupants, under-ride protection

Disclaimer
The views expressed are those of the authors, and not necessarily those of Monash University, VicRoads, or of the aforementioned organisations or people

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Preface

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Contents

EXECUTIVE SUMMARY IX

1. INTRODUCTION 1
   1.1 BACKGROUND 1
   1.2 AIM OF THE PROJECT 1
   1.3 PROJECT TASKS 1

2. DATA SOURCES AND ISSUES 3
   2.1 CRASH DATA 3
      2.1.1 State crash databases 3
      2.1.2 The ATSB Monthly Fatality Crash Database 4
      2.1.3 The ATSB Fatality File 4
   2.2 EXPOSURE DATA 4
   2.3 SPECIAL REPORTS 4

3. NATIONAL COMPARISONS 7
   3.1 GENERAL TRENDS 7
      3.1.1 Crash rates 7
   3.2 CRASH CHARACTERISTICS 9

4. ANALYSES OF VICTORIAN DATA 11
   4.1 GENERAL TRENDS 11
   4.2 CRASH CHARACTERISTICS 12
      4.2.1 Severity 12
      4.2.2 Time of day 13
      4.2.3 Location 13
      4.2.4 Speed zone 13
      4.2.5 Intersection vs. midblock crashes 16
      4.2.6 Crash type 17
      4.2.7 Type of traffic control 20
   4.3 ROAD USERS INVOLVED 22
      4.3.1 Metropolitan vs. rural areas 27
      4.3.2 Type of vehicle and road user 28
      4.3.3 Crash type 28
      4.3.4 The truck drivers 31

5. POTENTIAL BENEFITS OF UNDERRUN PROTECTION 35
   5.1 IDENTIFICATION OF POTENTIAL UNDERRUN CRASHES IN VICTORIAN DATA . 35
      5.1.1 Identifying crashes that could be influenced by front underrun protection 36
      5.1.2 Identifying crashes that could be influenced by side underrun protection 39
      5.1.3 Identifying crashes that could be influenced by rear underrun protection 39
      5.1.4 Summary 40
   5.2 ESTIMATE OF NUMBER OF UNDERRUN CRASHES AUSTRALIA-WIDE 43
   5.3 COST OF UNDERRUN CRASHES 44
   5.4 EFFECTIVENESS OF UNDERRUN PROTECTION DEVICES 45
   5.5 ESTIMATED BENEFITS OF UNDERRUN PROTECTION DEVICES 46

5.6 COST OF UNDERRUN PROTECTION DEVICES 47
5.7 CALCULATION OF ESTIMATED BENEFIT:COST RATIOS 47

6. SUMMARY AND CONCLUSIONS 49

6.1 NATIONAL COMPARISONS 49
6.2 TRUCK CRASHES IN VICTORIA 1996-2000 49
6.3 POTENTIAL BENEFITS OF UNDERRUN PROTECTION 51

REFERENCES 53

APPENDIX 1: CALCULATIONS OF BENEFIT:COST RATIOS 55

Figures

FIGURE 1. THE NUMBER OF FATAL ARTICULATED VEHICLE CRASHES AND THE NUMBER OF PERSONS KILLED IN VICTORIA AND AUSTRALIA SINCE 1990. FROM ATSB. 7
FIGURE 2. YEARLY TREND OF THE NUMBER OF TRUCK-INVOLVED CRASHES IN VICTORIA. 11
FIGURE 3. DISTRIBUTION OF CRASH SEVERITY FOR DAYTIME AND NIGHT-TIME CRASHES. 14
FIGURE 4. CRASH SEVERITY AS A FUNCTION OF SPEED ZONE. 16
FIGURE 5. YEARLY TREND OF FATALITIES. 26
FIGURE 6. YEARLY TREND OF SERIOUS INJURIES. 26
FIGURE 7. YEARLY TREND OF OTHER INJURIES 27

Tables

TABLE 1. NUMBER OF FATAL TRUCK CRASHES IN AUSTRALIA AND VICTORIA IN 1992, 1994 AND 1996. SOURCE: ATSB FATALITY FILE. 8
TABLE 2. NUMBER OF FATAL CRASHES INVOLVING ARTICULATED AND RIGID TRUCKS IN AUSTRALIA AND VICTORIA IN 1992, 1994 AND 1996. SOURCE: ATSB FATALITY FILE. 8
TABLE 3. FATALITY RATES DERIVED FROM 1996 FATAL CRASH DATA AND THE 1995 ABS SURVEY OF MOTOR VEHICLE USE. 8
TABLE 4. FATAL CRASH RATES FOR ARTICULATED AND RIGID TRUCKS IN VICTORIA AND AUSTRALIA IN 1997. 9
TABLE 5. SUMMARY OF CHARACTERISTICS OF FATAL TRUCK CRASHES IN AUSTRALIA AND VICTORIA IN 1992, 1994 AND 1996. SOURCE: ATSB FATALITY FILE. 10
TABLE 6. NUMBER OF TRUCK CRASHES IN VICTORIA. 11
TABLE 7. THE NUMBER OF CRASHES IN VICTORIA AT EACH LEVEL OF SEVERITY. 12
TABLE 8. CRASH SEVERITY AS A PERCENTAGE OF TOTAL CRASHES. 13
TABLE 9. TRUCK CRASHES BY TIME OF DAY. 14
TABLE 10. TRUCK CRASHES AS A FUNCTION OF METROPOLITAN/RURAL AREA AND CRASH SEVERITY. 15
TABLE 11. TRUCK CRASHES ACCORDING TO SPEED ZONE. 15
TABLE 12. TRUCK CRASHES BY SEVERITY AND LOCATION – INTERSECTION/MIDBLOCK AND METRO/RURAL. 17
TABLE 13. ARTICULATED TRUCK CRASHES BY SEVERITY AND CRASH CATEGORY (DCA CODE). 18
TABLE 14. RIGID CRASHES BY SEVERITY AND CRASH CATEGORY (DCA CODE). 19
TABLE 15. ALL TRUCK CRASHES BY SEVERITY AND CRASH CATEGORY (DCA CODE). 19
TABLE 16. METRO/RURAL CRASHES ACCORDING TO PRESENCE OF A TRAFFIC CONTROL DEVICE. 20
TABLE 17. TRUCK CRASHES FOR URBAN AND METROPOLITAN AREAS ACCORDING TO TYPE OF TRAFFIC CONTROL PRESENT. 21
TABLE 18. ARTICULATED TRUCK CRASHES BY CRASH CATEGORY (DCA) AND TYPE OF TRAFFIC CONTROL AND METROPOLITAN/RURAL LOCATION. 22
TABLE 19. RIGID CRASHES BY CRASH CATEGORY (DCA) AND TYPE OF TRAFFIC CONTROL AND METROPOLITAN/RURAL LOCATION. 23
TABLE 20. TRUCK CRASHES BY CRASH CATEGORY (DCA) AND TYPE OF TRAFFIC CONTROL AND METROPOLITAN/RURAL LOCATION. 24
TABLE 21. NUMBER OF PERSONS INJURED AT EACH LEVEL OF INJURY SEVERITY 25

TABLE 22. THE NUMBER OF PERSONS INJURED IN TRUCK CRASHES IN VICTORIA AT EACH LEVEL OF SEVERITY... 25
TABLE 23. PERSONS INJURED IN TRUCK CRASHES IN METROPOLITAN AND RURAL AREAS. ... 27
TABLE 24. INJURIES AS A FUNCTION OF TYPE OF OTHER VEHICLE INVOLVED IN CRASH. ... 29
TABLE 25. PERSONS INJURED IN ARTICULATED TRUCK CRASHES AS A FUNCTION OF CRASH TYPE (DCA CATEGORY). ... 30
TABLE 26. PERSONS INJURED IN RIGID TRUCK CRASHES AS A FUNCTION OF CRASH TYPE (DCA CATEGORY). ... 30
TABLE 27. PERSONS INJURED IN TRUCK CRASHES AS A FUNCTION OF CRASH TYPE (DCA CATEGORY). ... 31
TABLE 28. AGE DISTRIBUTION OF CRASH-INVOLVED TRUCK DRIVERS. ... 32
TABLE 29. GENDER DISTRIBUTION OF CRASH-INVOLVED TRUCK DRIVERS. ... 32
TABLE 30. STATE OF LICENSING OF CRASH-INVOLVED TRUCK DRIVERS. ... 33
TABLE 31. STATE OF REGISTRATION OF CRASH-INVOLVED TRUCKS. ... 33
TABLE 32. CRASHES POTENTIALLY ADDRESSED BY FRONT UNDERRUN PROTECTION – INVOLVING FRONT OF THE TRUCK AND THE REAR OF A LIGHT VEHICLE AS IDENTIFIED BY DCA CODE. ... 37
TABLE 33. CRASHES POTENTIALLY ADDRESSED BY FRONT UNDERRUN PROTECTION – CRASHES INVOLVING THE FRONT OF THE TRUCK AND THE FRONT OF THE LIGHT VEHICLE AS IDENTIFIED BY DCA CODE. ... 37
TABLE 34. CRASHES POTENTIALLY ADDRESSED BY FRONT UNDERRUN PROTECTION – INVOLVING FRONT OF THE TRUCK AND THE SIDE OF THE LIGHT VEHICLE AS IDENTIFIED BY DCA CODE. ... 38
TABLE 35. CRASHES POTENTIALLY ADDRESSED BY FRONT UNDERRUN PROTECTION – INVOLVING FRONT OF THE TRUCK AND THE SIDE OR REAR OF THE LIGHT VEHICLE AS IDENTIFIED BY DCA CODE. ... 38
TABLE 36. CRASHES POTENTIALLY ADDRESSED BY SIDE UNDERRUN PROTECTION – INVOLVING THE SIDE OF THE TRUCK AND THE FRONT OF THE LIGHT VEHICLE AS IDENTIFIED BY DCA CODE. ... 39
TABLE 37. CRASHES POTENTIALLY ADDRESSED BY REAR UNDERRUN PROTECTION – INVOLVING THE REAR OF THE TRUCK AND THE FRONT OF THE LIGHT VEHICLE AS IDENTIFIED BY DCA CODE. ... 40
TABLE 38. TOTAL NUMBER OF POTENTIAL UNDERRUN CRASHES SUMMARISED BY CRASH TYPE (DCA CODE). ... 41
TABLE 39. NUMBER OF POTENTIAL UNDERRUN CRASHES SUMMARISED BY CRASH SCENARIO. ... 42
TABLE 40. NUMBER OF POTENTIAL UNDERRUN CRASHES. VICTORIA 1996-2000. ADJUSTED FOR DOUBLE COUNTING. ... 43
TABLE 41. ESTIMATE OF ANNUAL NUMBER OF POTENTIAL UNDERRUN CRASHES AS A FUNCTION OF INJURY SEVERITY. AUSTRALIA. ... 44
TABLE 42. ESTIMATED ANNUAL COST ($000S) OF ESTIMATED NUMBER OF UNDERRUN CRASHES (NUMBER OF POTENTIAL CRASHES DIVIDED BY 2) INVOLVING A LIGHTER VEHICLE IN AUSTRALIA. BASED ON ESTIMATES OF CRASHES AUSTRALIA-WIDE 1996-2000 AND BTE (2000) CRASH COSTS TIMES 1.5 ... 45
TABLE 43. ESTIMATES FROM RECHNITZER (1993) TABLE 5.8. OF THE REDUCTIONS IN FATALITIES AND INJURY SEVERITY RESULTING FROM IMPROVED FRONTAL AND SIDE DESIGN OF TRUCKS. ... 46
TABLE 44. SUMMARY OF BENEFIT:COST RATIOS FOR A RANGE OF UNDERRUN PROTECTION MEASURES. ASSUMES DISCOUNT RATE OF 7% AND 15 YEAR LIFETIME. ... 48
TABLE 45. SUMMARY OF BENEFIT:COST RATIOS FOR A RANGE OF UNDERRUN PROTECTION MEASURES. ASSUMES DISCOUNT RATE OF 7% AND 25 YEAR LIFETIME. ... 48

EXECUTIVE SUMMARY

This report presents an updated statistical profile of the characteristics of heavy vehicle crashes in Victoria to provide a basis for estimating the benefits and costs of the recommended design improvements arising from the Stage 1 report on Underrun Protection.

National comparisons

Significant limitations exist in the availability, scope and timeliness of truck crash data, particularly for rigid trucks. Nevertheless, some comparisons between truck crashes in Victoria and nationally were undertaken. These analyses showed that

- Since 1997, the number of fatal crashes appears to have increased Australia-wide. In Victoria, the number of both rigid and articulated truck crashes has been steadily increasing between 1996 and 2000, with rigid truck crashes increasing at a slightly higher rate.
- In 1997, the fatality rates for articulated and rigid trucks (both in terms of registered vehicles and in terms of distance travelled) were lower in Victoria than for Australia as a whole. Otherwise, the characteristics of fatal truck crashes in Victoria and the rest of Australia in 1992, 1994 and 1996 are generally similar.
- Australia-wide and in Victoria, fatality rates (in terms of registered vehicles or distance travelled) are higher for articulated than rigid trucks.

Truck crashes in Victoria 1996-2000

From 1996-2000 there were 5,622 reported truck crashes in Victoria, of which 282 were fatal, 1656 resulted in serious injury and 3,684 resulted in other injury. About 40% of these crashes involved articulated trucks and 60% involved rigid trucks. A higher proportion of articulated truck crashes resulted in fatalities compared with rigid truck crashes.

Overall, 316 people were killed, 2,077 were seriously injured and 5,342 sustained some other injury in truck crashes in Victoria in 1996-2000. Of those killed, 177 were involved in articulated truck crashes and 147 were involved in rigid truck crashes. Car occupants were the largest group among those killed (64%), followed by truck occupants (16%), pedestrians (9%), motorcyclists (6%) and bicyclists (4%). At lower levels of severity, the representation of truck occupants increased and the representation of other road users decreased. Articulated truck crashes were almost twice as likely to result in death or serious injury to the truck occupant than rigid truck crashes.

About 80% of the crashes occurred during daylight hours but night-time crashes were generally more severe than daytime crashes. About three-quarters of the crashes occurred in metropolitan areas, although the proportion was lower for articulated than rigid truck crashes. The proportion of crashes resulting in death or serious injury increased with speed zone.

For both articulated and rigid trucks, the largest number of fatal crashes involved a collision between vehicles travelling in opposing directions – 'head-on' crashes. Same direction crashes were the most common type of serious injury and other injury crash for both articulated and rigid trucks.

Potential benefits of underrun protection

The Victorian road crash database does not allow crashes in which underrun occurred to be clearly identified. Crash types that could potentially result in underrun were identified using the Definitions for Coding Accidents (DCA) system, which provides a numerically coded description of the crash. During the period 1996-2000 inclusive, a total of 3,488 separate crashes were identified, where the crash could have involved underrun. In calculating benefit:cost ratios (BCRs), it was assumed that half of these crashes actually involved underrun.

The three most common types of crashes involved rigid trucks – a rigid truck hitting the rear of a lighter vehicle, followed by a lighter vehicle striking the side of a rigid truck and then a rigid truck running into the side of a lighter vehicle. The fourth, fifth and sixth most common types of crashes involved articulated trucks and followed a different pattern – an articulated truck hitting the rear of a light vehicle, followed by an articulated truck running into the side of a lighter vehicle, and then a lighter vehicle striking the side of an articulated truck.

Fatalities were most likely to occur in crashes involving the front of a truck. However, light vehicles running into the side of rigid trucks produced the highest number of serious injury crashes, followed by rigid trucks running into the side of lighter vehicles and then rigid trucks hitting the rear of lighter vehicles.

The analysis presented here assumed that front and side underrun protection will have the same level of effectiveness, changing 15% of fatal crashes to serious injury crashes and 30% of serious injury crashes to other injury crashes. It was assumed that rear underrun protection will change 30% of fatal crashes to serious injury crashes and 30% of serious injury crashes to other crashes.

For all of the underrun protection measures included, the BCRs were higher for articulated trucks than rigid trucks. The BCRs were higher when a 15-year lifetime was assumed, than when a 25-year lifetime was assumed. A package of front, side and rear underrun had a BCR of greater than 1 for both articulated trucks and rigid trucks, whether a 17- or 25-year lifetime is assumed. Not surprisingly, the BCR was doubled if the package cost $500, compared to if the package cost $1,000.

The BCRs also exceeded 1 for each type of underrun protection – front (at a cost of either $100 or $200), side or rear – for both articulated trucks and rigid trucks; again regardless of the lifetime. The BCRs were considerably larger for front underrun protection than for side underrun protection, with the lowest BCRs found for rear underrun protection.

1. INTRODUCTION

1.1 BACKGROUND

Heavy vehicles (GVM>3.5t) are involved in approximately 15% of serious injury and fatal crashes in Australia. Studies both in Australia and internationally have identified that there is a significantly increased injury risk to other road users where crashes involve heavy vehicles. In these crashes, some 80% of injuries are to the other road users.

Various studies have identified that a major contributing factor to injury risk in crashes involving heavy vehicles is the lack of compatibility with other road users. Various improvements to heavy vehicle design have been identified, including the provision of front, side and rear underrun protection. The need for improved crashworthiness of the cabin of heavy vehicles for increased driver protection in crashes has also been identified.

In addition to improvements in vehicle crashworthy design to reduce crash injury risk, crash prevention measures have also been identified in various studies. These include attention to the handling characteristics of heavy vehicles and attention to road design and infrastructure as they relate to heavy vehicle needs.

Although significant effort has gone into implementing improvements to the design of passenger vehicles, there are still considerable opportunities available to improve the safety of heavy vehicles and hence reduce their contribution to road trauma.

1.2 AIM OF THE PROJECT

The aim of the project is to produce an updated statistical profile of the characteristics of heavy vehicle crashes in Victoria and use this as a basis for estimating the benefits and costs of the recommended design improvements arising from the Stage 1 report on Underrun Protection.

1.3 PROJECT TASKS

The project task is to analyse available mass crash data to provide a profile of the characteristics of truck crashes in Victoria. From this analysis, the potential benefits of prevention of underrun crashes will be estimated.

2. DATA SOURCES AND ISSUES

2.1 CRASH DATA

In general terms, there are three types of data collections relating to truck crashes:

- state crash databases
- the Australian Transport Safety Bureau (ATSB) Monthly Fatality Crash Database
- the ATSB Fatality File

The scope and timeliness of these data collections differ as described below.

2.1.1 State crash databases

Each State and Territory maintains a database of information about road crashes occurring within their jurisdiction (including but not limited to those crashes involving trucks). The databases are compiled from Police report forms with some enhancement by the State road authority. The categories of crashes covered by the crash databases differ. All of the databases include crashes resulting in injury but some jurisdictions do not include non-injury crashes (e.g. Victoria). Other jurisdictions include non-injury crashes where the extent of property damage is above a certain threshold or a vehicle needs to be towed away. There is some concern about underreporting of minor crashes but this is less of an issue for truck crashes because injury is likely to occur or property damage is likely to be extensive.

Crash data in Victoria

Victoria Police collect data on each road crash in Victoria where they are notified of the incident. This includes instances where the Police attend the scene of the crash as well as cases where the crash is reported at a police station after the fact. In either case, the officer(s) dealing with the crash records a number of details regarding the incident, including information relating to the vehicles and to the individuals involved. VicRoads maintains a database of this information (termed “crash database” from here on) that includes only those crashes where an injury has occurred.

The analyses described in Section 4 of this report are based on the Victoria crash database for the period 1996-2000, inclusive. The database used is a recent and updated version (September 2001), where a number of previous anomalies have been rectified. Only crashes involving trucks are included – both rigid trucks and articulated trucks (semi truck-trailer combinations). Each crash may involve non-truck entities as well, such as cars or pedestrians.

Each database crash record is based on an individual person involved in the crash and provides information regarding injuries to individuals, damage to vehicles, the circumstances of the crash and the road environment. Each crash has a unique crash number and all parties involved in that crash share that number. Each record also lists up to four other parties involved in the crash and denotes the most severe level of injury that occurred in the crash. As such, each crash is adequately described by the record of just one party that was involved (with the caveat that if more than five trucks were involved in a single crash then there is a possibility that not all trucks in that particular crash will be included).

The crash-based analysis described in Section 4 is based on a single crash record for each crash – there were 5,622 crashes in Victoria that involved trucks in the period 1996-2000 inclusive. The person-based analysis takes account of all records – there were 15,913 parties involved in crashes that involved at least one truck over the same period. The underrun analysis is based on the crash-based record. In all analyses rigid trucks and articulated trucks are considered separately, along with all trucks (the combination of these categories).

It should be noted that the definitions for a rigid truck and an articulated truck as recorded in the database have been coded subjectively by the police officers attending the scene. There is no mass criterion that separates a truck from a utility or four-wheel drive with a tray. It is essentially the police officer's decision at the scene as to how the vehicle should be recorded.

2.1.2 The ATSB Monthly Fatality Crash Database

The Australian Transport Safety Bureau maintains a Monthly Fatality Crash Database which includes basic information on fatal crashes involving articulated trucks (not rigid trucks). The data items include: date of crash, speed zone, type of crash (single truck, pedestrian, multiple vehicle), State or Territory the crash occurred in and day or night.

2.1.3 The ATSB Fatality File

The ATSB Fatality File combines information from crash databases and coronial records for all fatal crashes (including those involving trucks). It is available for a range of years (e.g. 1992, 1994, 1996, 1997) but is generally not available for several years after the occurrence of the crash. Thus, it is a source of detailed but not timely data on a relatively small sample of crashes.

2.2 EXPOSURE DATA

Exposure data describe the amount and type of use of vehicles. Thus, they provide denominator data in the calculation of crash rates. The most commonly used data source for truck exposure is the Australian Bureau of Statistic's Survey of Motor Vehicle Use (SMVU). The SMVU provides information on the number of articulated and rigid trucks (and other vehicles) registered in each State and Territory and how far they have travelled in the 12 months of the survey period. The SMVU is now available annually and so is about as timely as the crash data.

There are several drawbacks to using the SMVU, however. Firstly, the method used in the Survey changed after 1995. Thus, estimates before and after 1995 are not strictly comparable. Secondly, the distance travelled data relate to distances travelled by trucks according to where they are registered. The generally available data do not provide information on how much travel occurs in each State (which is needed for crash rates).

2.3 SPECIAL REPORTS

A number of special reports have been published that provide information about truck crashes. The most recent is:

ATSB. (2001). Articulated truck crashes. Monograph 8. Canberra: Australian Transport Safety Bureau.

3. NATIONAL COMPARISONS

3.1 GENERAL TRENDS

The number of fatal articulated vehicle crashes and the number of persons killed in Victoria and Australia since 1990 is shown in Figure 1. There was a reduction from 1990 to 1991. From 1991 to 1997, the number of articulated vehicle crashes was reasonably constant. Since 1997, the number of crashes appears to have increased Australia-wide but this trend is not as evident in Victoria.

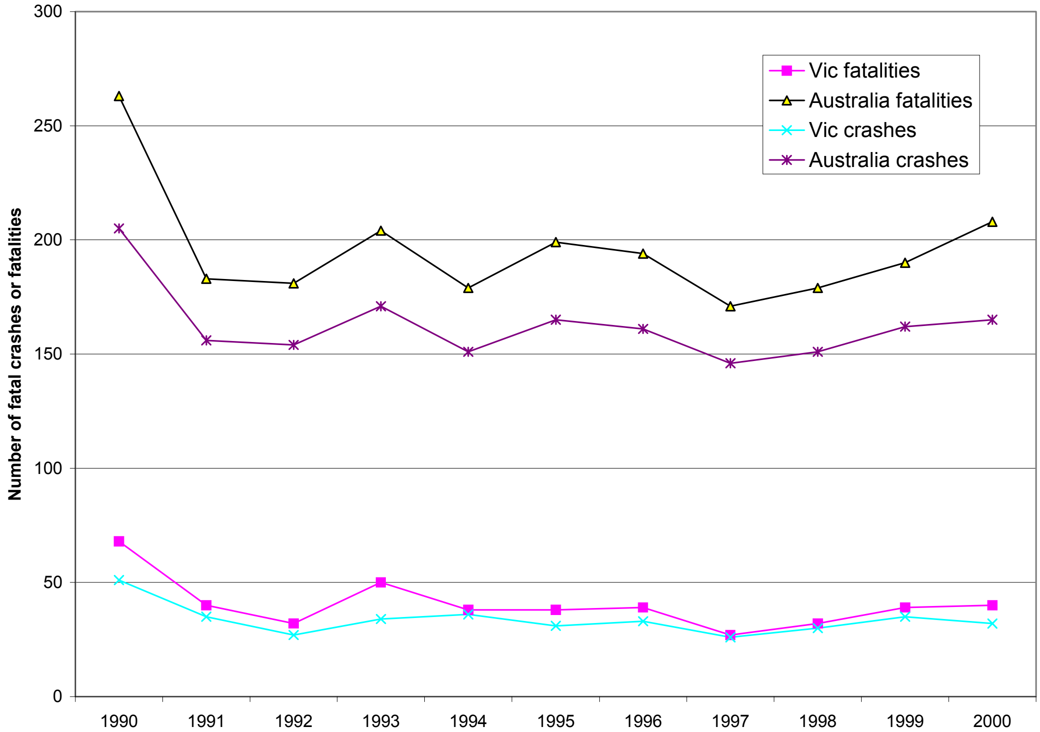


Figure 1. The number of fatal articulated vehicle crashes and the number of persons killed in Victoria and Australia since 1990. From ATSB.

In 1992, 1994 and 1996 there was a total of 780 fatal truck crashes in Australia. Of these crashes, 146 (18.7%) occurred in Victoria (see Table 1). During this period, 19.9% of the fatal articulated truck crashes and 17.2% of the fatal rigid truck crashes occurred in Victoria (see Table 2).

3.1.1 Crash rates

Australia-wide data show that fatality rates are higher for articulated than rigid trucks regardless of whether registered vehicles or distance travelled is used as the denominator (Table 3).

Crash rates as a function of distance travelled for particular jurisdictions are available only for those years for which information is available about travel in particular jurisdictions. Table 4 shows that in 1997, the number of fatal articulated truck crashes per 100 million vehicle kilometres travelled was 2.66 for Australia as a whole and 2.08 in Victoria. The number of persons killed in articulated truck crashes per 100 million vehicle kilometres travelled was 3.12 for Australia as a whole and 2.16 in Victoria. The number of persons killed in rigid truck crashes per 100 million vehicle kilometres travelled was also higher Australia-wide than in Victoria. The fatality rates in terms of registered trucks showed the same pattern.

Table 1. Number of fatal truck crashes in Australia and Victoria in 1992, 1994 and 1996. Source: ATSB Fatality File.

Year	Victoria	Other States and Territories	Australia
1992	50 (18.5%)	220 (81.5%)	270 (100%)
1994	50 (18.9%)	215 (81.1%)	265 (100%)
1996	46 (18.8%)	199 (81.2%)	245 (100%)
Total	146 (18.7%)	634 (81.3%)	780 (100%)

Table 2. Number of fatal crashes involving articulated and rigid trucks in Australia and Victoria in 1992, 1994 and 1996. Source: ATSB Fatality File.

Fatal crashes involving	Victoria	Other States and Territories	Australia
Articulated trucks	93 (19.9%)	375 (80.1%)	468 (100%)
Rigid trucks	56 (17.2%)	270 (82.8%)	326 (100%)

Table 3. Fatality rates derived from 1996 fatal crash data and the 1995 ABS Survey of Motor Vehicle Use.

Measure	**Articulated trucks**	**Rigid trucks**	**Total**
Fatal crashes	154	95	245
Fatalities	188	110	294
Fatal crashes per 10,000 vehicles	26.58	2.83	6.23
Fatalities per 10,000 vehicles	32.45	3.28	7.47
Fatal crashes per 100 million kms travelled	3.02	1.41	2.07
Fatalities per 100 million kms travelled	3.69	1.64	2.49

Table 4. Fatal crash rates for articulated and rigid trucks in Victoria and Australia in 1997.

	Articulated trucks		Rigid trucks	
	Australia	Victoria	Australia	Victoria
Number of fatal crashes	146	26	n.a.	25
Number of fatalities	171	27	116	25
Number of trucks registered	58,794	16,946	335,430	82,674
Distance travelled (100 million km)	54.8	12.5	53.8	12.9
Fatal crashes per 10,000 registered trucks	24.8	15.3	-	3.0
Fatalities per 10,000 registered trucks	29.1	15.9	3.5	3.0
Fatal crashes per 100 million km	2.66	2.08	-	1.93
Fatalities per 100 million km	3.12	2.16	2.15	1.93

3.2 CRASH CHARACTERISTICS

Table 5 summarises the characteristics of the fatal truck crashes in Victoria and the rest of Australia in 1992, 1994 and 1996. Overall, 14% of fatal truck crashes involved a single truck only, 11.5% involved a truck and a pedestrian, and 74.5% were multiple-vehicle crashes. The patterns for Victoria and the rest of Australia did not differ significantly.

In Australia as a whole, 15% of fatal truck crashes occurred on divided roads, 67% on undivided roads and information was unknown for 18% of crashes. The patterns for Victoria and the rest of Australia did not differ significantly (see Table 5).

In Victoria, a larger proportion of fatal truck crashes occurred in the capital city and in rural areas and a smaller proportion occurred in other urban areas compared to other States and Territories.

In all jurisdictions, about two-thirds of fatal truck crashes occurred during daytime (6 am to 6 pm) and about one-third at night (6 pm to 6 am).

Table 5. Summary of characteristics of fatal truck crashes in Australia and Victoria in 1992, 1994 and 1996. Source: ATSB Fatality File.

Characteristic	Victoria	Other States and Territories	Australia
Crash type			
Single truck only	18 (12.3%)	91 (14.4%)	109 (14.0%)
Truck-pedestrian	15 (10.3%)	75 (11.8%)	90 (11.5%)
Multiple vehicle	113 (77.4%)	468 (73.8%)	581 (74.5%)
Road type			
Divided	26 (17.8%)	90 (14.2%)	116 (14.9%)
Undivided	92 (63.0%)	434 (68.5%)	526 (67.4%)
Unknown	28 (19.2%)	110 (17.4%)	138 (17.7%)
Location			
Capital city	48 (32.9%)	140 (22.1%)	188 (24.1%)
Other urban	14 (9.6%)	153 (24.1%)	167 (21.4%)
Rural	84 (57.5%)	324 (51.1%)	408 (52.3%)
Unknown	0 (0.0%)	17 (2.7%)	17 (2.2%)
Time of day			
6 am – 6 pm	102 (69.9%)	411 (64.8%)	513 (65.8%)
6 pm – 6 am	44 (30.1%)	223 (35.2%)	267 (34.2%)

4. ANALYSES OF VICTORIAN DATA

4.1 GENERAL TRENDS

This section of the report presents an analysis of the numbers and characteristics of truck-involved crashes in Victoria in the period 1996-2000. Table 6 and Figure 2 examine the yearly trend of truck-involved crashes. The statistics are divided into articulated trucks and rigid trucks. It should be noted that the total number of truck-involved crashes ("Truck" used in some tables in the report) does not necessarily equate to the simple addition of articulated-involved and rigid-involved collisions. For example, in 1996 there were 444 crashes reported to the police that involved an articulated truck, and 646 crashes that involved rigid trucks. However, overall there were 1,075 truck-involved crashes, rather than 1,090 crashes as would result from combining the two categories. This indicates that 15 crashes involved at least one articulated truck and at least one rigid truck.

Table 6. Number of truck crashes in Victoria.

	1996	1997	1998	1999	2000	Total
Artic	444	429	462	504	450	**2289**
Rigid	646	702	672	709	715	**3444**
Truck	1075	1113	1108	1187	1139	**5622**

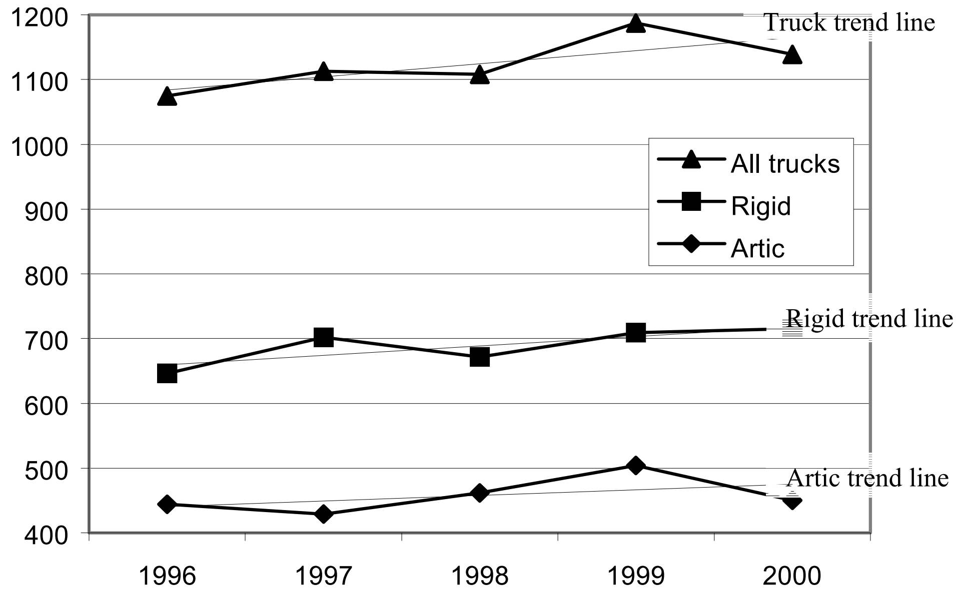


Figure 2. Yearly trend of the number of truck-involved crashes in Victoria.

As demonstrated by the trend lines in Figure 2, the number of truck-involved crashes for both rigid and articulated trucks has been steadily increasing over time between 1996 and 2000, with rigid truck crashes increasing at a slightly higher rate.

4.2 CRASH CHARACTERISTICS

4.2.1 Severity

Each crash record includes a classification of the overall severity of the crash. This variable can take the values of "Fatal", "Serious injury" or "Other injury", and indicates the most severe injury sustained in the crash. Hence, a crash recorded as "fatal" indicates that there was at least one fatality associated with the crash. It does not indicate the number of fatalities or the number and presence of serious injuries or other injuries.

The number of crashes at each level of severity is summarised in Table 7. Table 8 shows the number of crashes at each level of severity in both absolute and relative terms. Approximately two-thirds of truck-involved crashes resulted in an "other injury" as the most severe injury for the crash. Just under one-third of crashes for each truck category resulted in a "serious injury", and less than 10% of crashes were classified as a fatality. A higher proportion of articulated truck crashes result in fatalities compared with rigid truck crashes – 7% versus 4% respectively.

Table 7. The number of crashes in Victoria at each level of severity.

	1996	1997	1998	1999	2000
Fatal					
Artic	33	26	30	35	32
Rigid	17	25	28	34	29
Truck	48	51	57	66	60
Serious injury					
Artic	134	103	151	147	141
Rigid	179	202	211	215	212
Truck	308	299	355	349	345
Other injury					
Artic	277	300	281	322	277
Rigid	450	475	433	460	474
Truck	719	763	696	772	734

Table 8. Crash severity as a percentage of total crashes.

	Fatal		Serious injury		Other injury		Total
	No.	% of total	No.	% of total	No.	% of total	
Articulated	156	7%	676	30%	1457	64%	**2289**
Rigid	133	4%	1019	30%	2292	67%	**3444**
Truck	282	5%	1656	29%	3684	66%	**5622**

4.2.2 Time of day

Table 9 explores the influence of time of day on the number of truck crashes – divided into daylight hours (6am-6pm) versus hours of darkness (6pm-6am). Overall, 79% of truck crashes occurred during daylight hours (72% of articulated truck crashes and 85% of rigid truck crashes). For each truck type the number of each type of injury crash is substantially greater during daylight hours than during darkness. However, this may be an issue of exposure as well as risk – it is expected that there would be fewer trucks travelling during darkness compared to daylight hours.

Figure 3 shows that night-time crashes were generally more severe than daytime crashes. This may reflect higher travel speeds at night because of less traffic congestion.

4.2.3 Location

Table 10 shows that most truck crashes occurred in metropolitan areas – 61% of all articulated truck crashes, 82% of all rigid truck crashes, and 74% of all truck-involved crashes. Fatal crashes involving articulated trucks are the only type of truck crash that is more common in rural areas than in the metropolitan area.

4.2.4 Speed zone

Table 11 summarises the occurrence of truck-involved crashes according to the speed zone in which the crash occurred. For the purposes of this analysis, the nine separate speed zones in the database were collapsed into low speed areas (40-60 km/h), medium speed areas (70-90 km/h), and high speed areas (100+ km/h). Across all injury types and truck types, the number of crashes is highest in high speed areas followed by low speed areas. This may reflect the preponderance of these two zones relative to the number of medium speed areas.

Table 9. Truck crashes by time of day.

	Crash time	Crash Severity			Total
		Fatal	Serious injury	Other injury	
Articulated	6am-6pm	90	459	1098	1647
	6pm-6am	66	217	359	642
	Total	156	676	1457	2289
Rigid	6am-6pm	104	827	1984	2915
	6pm-6am	29	192	308	529
	Total	133	1019	2292	3444
Truck	6am-6pm	190	1253	3023	4466
	6pm-6am	92	403	661	1156
	Total	282	1656	3684	5622

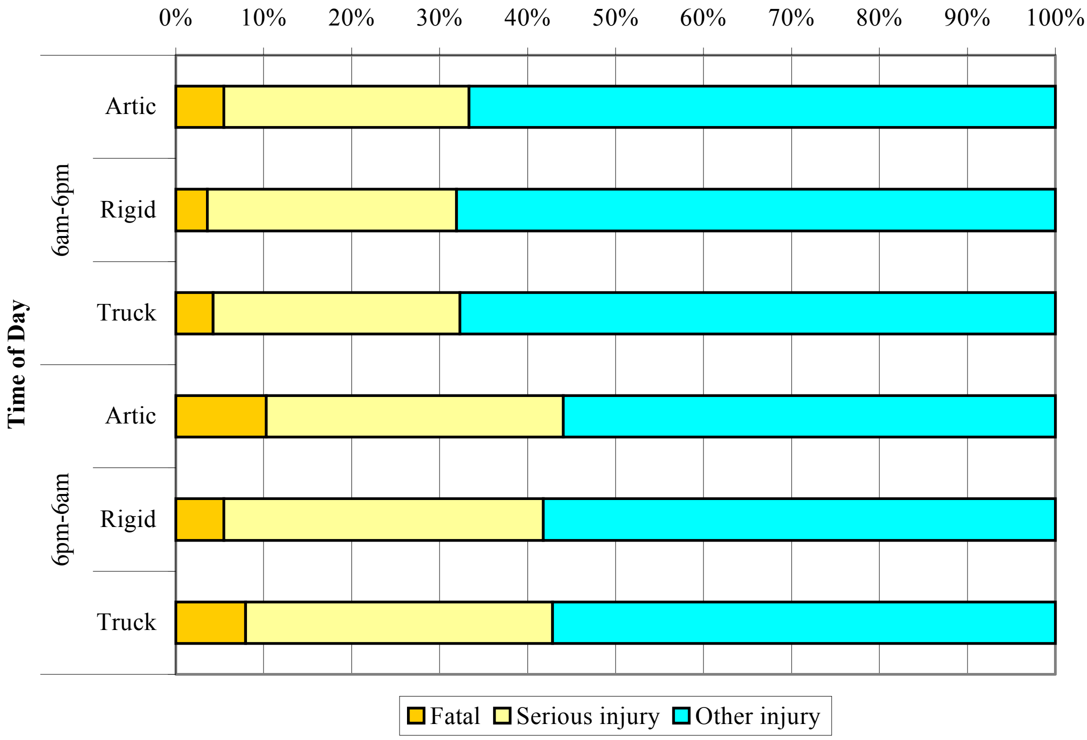


Figure 3. Distribution of crash severity for daytime and night-time crashes.

Table 10. Truck crashes as a function of metropolitan/rural area and crash severity.

	LGA type	Crash Severity			Total
		Fatal	Serious injury	Other injury	
Artic	Metro	51	380	962	**1393**
	Rural	105	295	495	**895**
	Total	156	675	1457	**2288**
Rigid	Metro	86	816	1929	**2831**
	Rural	47	203	363	**613**
	Total	133	1019	2292	**3444**
Truck	Metro	135	1178	2843	**4156**
	Rural	147	477	841	**1465**
	Total	282	1655	3684	**5621**

Table 11. Truck crashes according to speed zone.

	Speed zone	Crash severity			Total
		Fatal	Serious injury	Other injury	
Artic	40-60	22	186	483	691
	70-90	23	187	426	636
	100 +	111	303	545	959
	Unknown			3	3
	Total	156	676	1457	2289
Rigid	40-60	38	498	1273	1809
	70-90	35	264	603	902
	100 +	60	253	409	722
	Unknown		4	7	11
	Total	133	1019	2292	3444
Truck	40-60	60	676	1739	2475
	70-90	58	444	1013	1515
	100 +	164	532	922	1618
	Unknown		4	10	14
	Total	282	1656	3684	5622

The greatest number of articulated-involved fatal crashes occur in high speed areas – approximately double the combined number of fatalities across all other speed limit zones. The number of serious injury and other injury articulated truck crashes is also highest for high speed areas, and the number of these injury crashes occurring in low and medium speed areas is approximately equivalent.

The pattern is somewhat different for rigid trucks. In the case of rigid truck-involved crashes, the greatest number of fatality crashes occurred in high speed areas, but both serious and other injuries were more likely in low speed areas. In terms of the total number of injury crashes, low speed areas have the greatest number of crashes, followed by the medium speed areas, with high speed zones reflected by the least number of injury crashes.

For trucks overall, low speed areas had the highest number of injury crashes, followed by high speed areas and then mid-speed areas.

Figure 4 indicates that the proportion of crashes resulting in death or serious injury increased with speed zone. In low speed zones and high speed zones, articulated truck crashes were more likely to be fatal than rigid truck crashes.

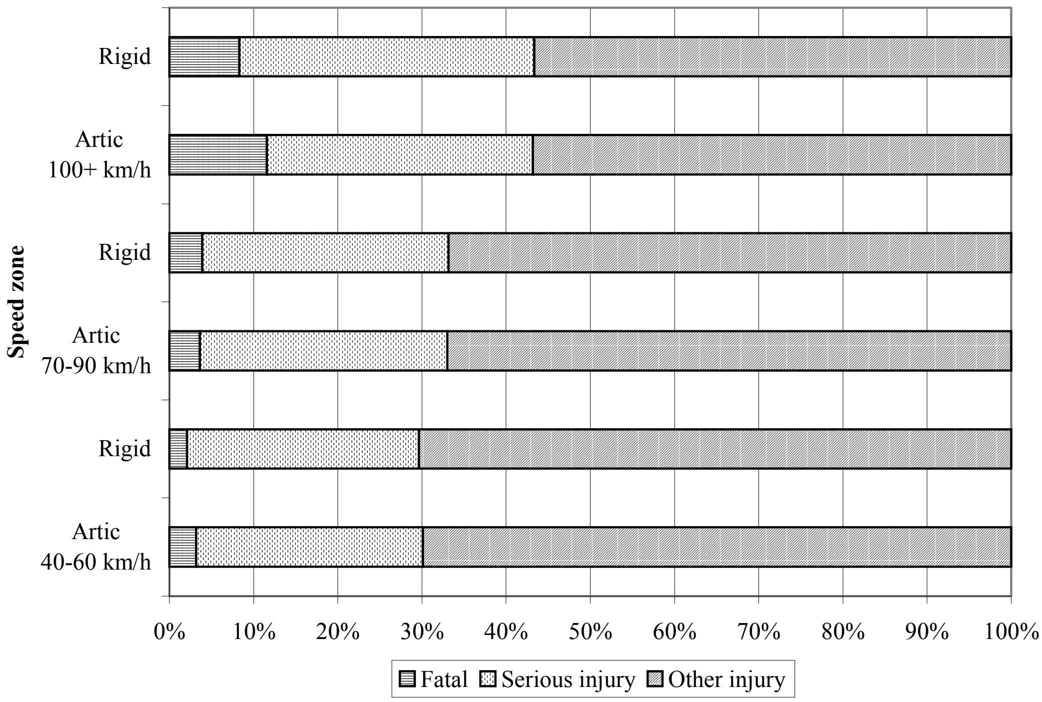


Figure 4. Crash severity as a function of speed zone.

4.2.5 Intersection vs. midblock crashes

A further variable that describes each crash is whether it occurred at an intersection or on a stretch of road between intersections (a midblock) – see Table 12. Overall, 47% of truck crashes occurred at intersections (41% of articulated truck crashes and 50% of rigid truck crashes).

As would be expected, the ratio of the number of midblock crashes to intersection crashes is substantially higher for rural areas, probably due in large part to the fact that there are relatively fewer intersections. Among metropolitan crashes, 52% of truck crashes occurred at intersections (49% of metropolitan articulated truck crashes and 53% of metropolitan rigid truck crashes).

Table 12. Truck crashes by severity and location – intersection/midblock and metro/rural.

			Crash Severity			Total
			Fatal	Serious injury	Other injury	
Articulated	Metro	Intersection	21	188	478	**687**
		Midblock	30	192	484	**706**
	Rural	Intersection	30	78	148	**256**
		Midblock	75	216	347	**638**
Rigid	Metro	Intersection	38	385	1083	**1506**
		Midblock	48	431	844	**1323**
	Rural	Intersection	16	77	131	**224**
		Midblock	31	126	232	**389**
Truck	Metro	Intersection	58	566	1543	**2167**
		Midblock	77	612	1298	**1987**
	Rural	Intersection	44	146	275	**465**
		Midblock	103	330	566	**999**

In metropolitan areas, midblock crashes were more highly represented among fatal crashes than intersection crashes. This pattern was not evident for rural crashes.

4.2.6 Crash type

VicRoads uses a numerical system for categorising crashes that provides some detail as to how a crash occurred. The structure is called the Definitions for Classifying Accidents (DCA) coding system. Individual DCA codes are grouped according to a number of categories:

- Crashes that involved a pedestrian
- Crashes that occurred between vehicles approaching from adjacent directions (intersections only)
- Crashes that occurred between vehicles travelling in opposing directions

- Crashes that occurred between vehicles travelling in the same direction
- Crashes that occurred while a vehicle was manoeuvring
- Crashes that occurred while a vehicle was overtaking
- Crashes between a vehicle and an obstacle in the path of travel
- Crashes that occurred when a vehicle left a straight roadway
- Crashes that occurred when a vehicle left a curved roadway
- Miscellaneous crashes.

Tables 13 to 15 summarise the number of crashes in each DCA group for articulated trucks, rigid trucks and all trucks. Overall, the largest number of crashes for both articulated and rigid trucks involved vehicles travelling in the same direction. For both articulated and rigid truck crashes, the largest number of fatal crashes involved a collision between vehicles travelling in opposing directions – 'head-on' crashes. Same direction crashes were the most common type of serious injury and other injury crash for both articulated and rigid trucks.

Table 13. Articulated truck crashes by severity and crash category (DCA code).

DCA category	**Crash Severity**			**Total**
	Fatal	**Serious injury**	**Other injury**	
Pedestrian	13	23	15	**51**
Adjacent vehicle	25	85	130	**240**
Opposing direction	55	87	128	**270**
Same direction	17	208	701	**926**
Manoeuvring	12	40	55	**107**
Overtaking	8	18	33	**59**
On path	2	38	64	**104**
Off path straight	7	84	161	**252**
Off path curve	15	77	147	**239**
Miscellaneous	2	16	23	**41**
Total	**156**	**676**	**1457**	**2289**

Table 14. Rigid crashes by severity and crash category (DCA code).

DCA category	Crash Severity			Total
	Fatal	Serious injury	Other injury	
Pedestrian	14	77	75	**166**
Adjacent vehicle	28	169	326	**523**
Opposing direction	42	176	264	**482**
Same direction	15	280	955	**1250**
Manoeuvring	9	63	168	**240**
Overtaking	3	23	51	**77**
On path	10	93	180	**283**
Off path straight	3	74	169	**246**
Off path curve	6	40	65	**111**
Miscellaneous	3	24	39	**66**
Total	**133**	**1019**	**2292**	**3444**

Table 15. All truck crashes by severity and crash category (DCA code).

DCA category	Crash Severity			Total
	Fatal	Serious injury	Other injury	
Pedestrian	26	99	90	**215**
Adjacent vehicle	52	250	450	**752**
Opposing direction	95	258	387	**740**
Same direction	30	466	1614	**2110**
Manoeuvring	21	103	222	**346**
Overtaking	10	36	82	**128**
On path	12	130	239	**381**
Off path straight	10	158	328	**496**
Off path curve	21	117	212	**350**
Miscellaneous	5	39	60	**104**
Total	**282**	**1656**	**3684**	**5622**

4.2.7 Type of traffic control

The crash database records the type of traffic control present at the scene, such as a set of traffic lights or a roundabout. Table 16 presents the number of injury crashes (and percentage of the totals) that occurred in metropolitan and rural areas according to whether the crash occurred at a traffic control device or not. Entries of "unknown" and "missing" are the same for the purposes of this analysis. "Missing" corresponds to where no data were entered into the database as opposed to instances where "unknown" was recorded.

Table 16. Metro/rural crashes according to presence of a traffic control device.

	Artic				Rigid				Truck			
	Metro		Rural		Metro		Rural		Metro		Rural	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Controlled	455	33%	129	14%	905	32%	132	22%	1344	32%	255	17%
Uncontrolled	877	63%	738	82%	1712	60%	459	75%	2539	61%	1160	79%
Unknown	15	1%	12	1%	29	1%	3	0%	44	1%	15	1%
Missing	46	3%	16	2%	185	7%	19	3%	229	6%	35	2%
Total	**1393**	**100%**	**895**	**100%**	**2831**	**100%**	**613**	**100%**	**4156**	**100%**	**1465**	**100%**

Overall, a traffic control device was present for 32% of metropolitan crashes and 17% of rural crashes. In metropolitan areas, traffic control devices were equally common at the site of articulated compared to rigid truck crashes. In rural areas, traffic control devices were more likely to be found at the sites of rigid truck crashes (22%) than articulated truck crashes (14%).

Table 17 provides more detail on the types of traffic controls present at the crash sites (those listed as "missing" in Table 15 are not included). Stop-go lights followed by give-way signs, were the most traffic control devices at the sites of articulated truck crashes in metropolitan areas. For articulated truck crashes in rural areas, the most likely traffic control device present was a give-way sign. Rigid truck crashes in metropolitan areas were also most likely to occur at stop-go lights, however stop signs and roundabouts were the next most likely locations. For rigid truck crashes in rural areas, stop signs were the most likely traffic control present. Give-way signs were one of the least common devices present for rigid trucks in either metropolitan or rural crashes involving an injury.

Table 17. Truck crashes for urban and metropolitan areas according to type of traffic control present.

Traffic control	Articulated		Rigid		Truck	
	Metro	Rural	Metro	Rural	Metro	Rural
No control	877	738	1712	459	2539	1160
Stop-go lights	327	19	534	25	852	44
Flashing lights	4		5		9	
Out of order	1	2	4		5	2
Pedestrian lights	5	1	5		9	1
Pedestrian crossing			8		8	
Railway crossing gates & booms	1		6		7	
Railway crossing bells & lights		3	2		2	3
Railway crossing no control		4	39	7		4
Roundabout	19	6	113	18	57	13
Stop sign	31	17	158	71	143	33
Give way sign	54	71	2	1	210	139
School - flags					2	1
Police	1		1		2	
Other	12	6	28	10	38	15
Unknown	15	12	29	3	44	15
Total	**1347**	**879**	**2646**	**594**	**3927**	**1430**

Tables 18 to 20 summarise the characteristics of truck crashes at the most common types of traffic controls. Stop-go lights and give-way signs were the most common traffic control devices present for crashes involving a truck in metropolitan and rural areas respectively. Most of the truck crashes at stop-go lights in metropolitan areas involved vehicles travelling in the same direction. About 20% of these crashes involved adjacent vehicles and about another 20% involved vehicles from opposing directions. The bulk of truck crashes in metropolitan areas that occurred at stop and give way signs involved adjacent vehicles. For truck crashes at give-way signs in rural areas, the most likely crash category was “adjacent vehicle”.

4.3 ROAD USERS INVOLVED

Overall, 316 people were killed, 2,077 were seriously injured and 5,342 sustained some other injury in truck crashes in Victoria in 1996-2000 (see Table 21). Of those killed, 177 were involved in articulated truck crashes and 147 were involved in rigid truck crashes.

Articulated truck crashes were generally more severe than rigid truck crashes (see Table 21). Almost 3% of persons in articulated truck crashes were killed, compared to about 1.5% of persons in rigid truck crashes.

Table 22 and Figures 5 to 7 summarise the yearly trend of number of injuries in articulated- and rigid-involved crashes, as well as all truck crashes. Generally, articulated-involved crashes produced more fatalities (except for 1998) than rigid crashes, but rigid-involved produced a greater number of serious injuries, other injuries and instances of non-injuries as a result of a crash.

Table 18. Articulated truck crashes by crash category (DCA) and type of traffic control and metropolitan/rural location.

Traffic control	DCA Category									**Total**
	Adjacent vehicle	Opposing direction	Same direction	Manoeuvre	Overtaking	On path	Off path straight	Off path curve	Misc	
Metropolitan area										
No control	12	83	512	70	15	66	61	43	15	**877**
Stop-go lights	66	63	169	10	2	2	12	1	2	**327**
Flashing lights	2		2							**4**
Out of order	1									**1**
Pedestrian lights		1	4							**5**
Railway crossing gates & booms									1	**1**
Roundabout	4		9				4	2		**19**
Stop sign	23	2	3	1			2			**31**
Give way sign	36	1	13				3	1		**54**
Police		1								**1**
Other	1	2	5			3			1	**12**
Unknown		2	7			1	3	1	1	**15**
Total	**145**	**155**	**724**	**81**	**17**	**72**	**85**	**48**	**20**	**1347**
Rural areas										
No control	12	106	178	26	40	26	151	186	13	**738**
Stop-go lights	9	4	6							**19**
Out of order	1		1							**2**
Pedestrian lights			1							**1**
Railway crossing bells & lights							1		2	**3**
Railway crossing no control									4	**4**
Roundabout	1		1				3	1		**6**
Stop sign	15						2			**17**
Give way sign	54	2	9				3	1	2	**71**
Other	1	1	1			1	1	1		**6**
Unknown	1	2	1		2		4	2		**12**
Total	**94**	**115**	**198**	**26**	**42**	**27**	**165**	**191**	**21**	**879**

Table 19. Rigid crashes by crash category (DCA) and type of traffic control and metropolitan/rural location.

Traffic Control	DCA Category									Total
	Adjacent vehicle	Opposing direction	Same direction	Manoeuvring	Overtaking	On path	Off path straight	Off path curve	Misc	
Metropolitan area										
No control	49	231	775	179	45	222	134	33	44	**1712**
Stop-go lights	136	127	245	14		2	9		1	**534**
Flashing lights	1	1	3							**5**
Out of order	2	2								**4**
Pedestrian lights		1	4							**5**
Pedestrian crossing			6	2						**8**
Railway crossing gates & booms			4			1			1	**6**
Railway crossing bells & lights			1						1	**2**
Roundabout	15	3	13	1		1	4	2		**39**
Stop sign	87	6	1	6	1	1	9	2		**113**
Give way sign	123	6	20	3	1		3	1	1	**158**
School - flags			2							**2**
Police			1							**1**
Other	5	3	10	1		9				**28**
Unknown	1	2	19	1		1	4		1	**29**
Total	**419**	**382**	**1104**	**207**	**47**	**237**	**163**	**38**	**49**	**2646**
Rural areas										
No control	18	90	109	30	28	32	72	70	10	**459**
Stop-go lights	2	5	18							**25**
Roundabout	4	1	1					1		**7**
Stop sign	16					1	1			**18**
Give way sign	59	1	2	1		1	6	1		**71**
School - flags			1							**1**
Other	2	2	4	1	1					**10**
Unknown	1		1					1		**3**
Total	**102**	**99**	**136**	**32**	**29**	**34**	**79**	**73**	**10**	**594**

Table 20. Truck crashes by crash category (DCA) and type of traffic control and metropolitan/rural location.

Traffic control	DCA Category									**Total**
	Adjacent vehicle	Opposing direction	Same direction	Manoeuvring	Overtaking	On path	Off path straight	Off path curve	Misc	
Metropolitan area										
No control	61	311	1247	248	58	287	193	76	58	**2539**
Stop-go lights	200	189	408	24	2	4	21	1	3	**852**
Flashing lights	3	1	5							**9**
Out of order	3	2								**5**
Pedestrian lights		1	8							**9**
Pedestrian crossing			6	2						**8**
Railway crossing gates & booms			4			1			2	**7**
Railway crossing bells & lights			1						1	**2**
Roundabout	18	3	22	1		1	8	4		**57**
Stop sign	109	8	4	7	1	1	11	2		**143**
Give way sign	158	7	32	3	1		6	2	1	**210**
School - flags			2							**2**
Police		1	1							**2**
Other	6	5	14	1		11			1	**38**
Unknown	1	4	26	1		2	7	1	2	**44**
Total	**559**	**532**	**1780**	**287**	**62**	**307**	**246**	**86**	**68**	**3927**
Rural areas										
No control	29	190	269	56	62	54	223	256	21	**1160**
Stop-go lights	11	9	24							**44**
Out of order	1		1							**2**
Pedestrian lights			1							**1**
Railway crossing bells & lights							1		2	**3**
Railway crossing no control									4	**4**
Roundabout	5	1	2				3	2		**13**
Stop sign	29					1	3			**33**
Give way sign	110	3	11	1		1	9	2	2	**139**
School - flags			1							**1**
Other	3	2	5	1	1	1	1	1		**15**
Unknown	2	2	2		2		4	3		**15**
Total	**190**	**207**	**316**	**58**	**65**	**57**	**244**	**264**	**29**	**1430**

Table 21. Number of persons injured at each level of injury severity

	Injury severity				Total
	Fatal injury	Serious injury	Other injury	Non injury	
Artic	177	887	2119	2910	**6093**
% of Artic total	*2.9%*	*14.6%*	*34.8%*	*47.8%*	
Rigid	147	1242	3310	5031	**9730**
% of Rigid total	*1.5%*	*12.8%*	*34.0%*	*51.7%*	
Truck	316	2077	5342	7795	**15530**
% of Truck total	*2.0%*	*13.4%*	*34.4%*	*50.2%*	

Table 22. The number of persons injured in truck crashes in Victoria at each level of severity.

	1996	**1997**	**1998**	**1999**	**2000**
Fatal					
Artic	39	27	32	39	40
Rigid	22	25	34	36	30
Truck	58	52	65	72	69
Serious injury					
Artic	188	140	192	192	175
Rigid	219	244	247	261	271
Truck	399	375	431	434	438
Other injury					
Artic	380	423	405	483	428
Rigid	649	670	619	664	708
Truck	1021	1074	1010	1126	1111
Non-injury					
Artic	558	523	555	701	573
Rigid	941	999	984	1024	1083
Truck	1481	1491	1511	1689	1623

Plotting each of the injury types as a function of time produces Figures 5 to 7. In some cases the gradient is not steep, however trend lines indicate that the number of each type of injury for both rigid and articulated trucks has been on the increase between 1996 and 2000.

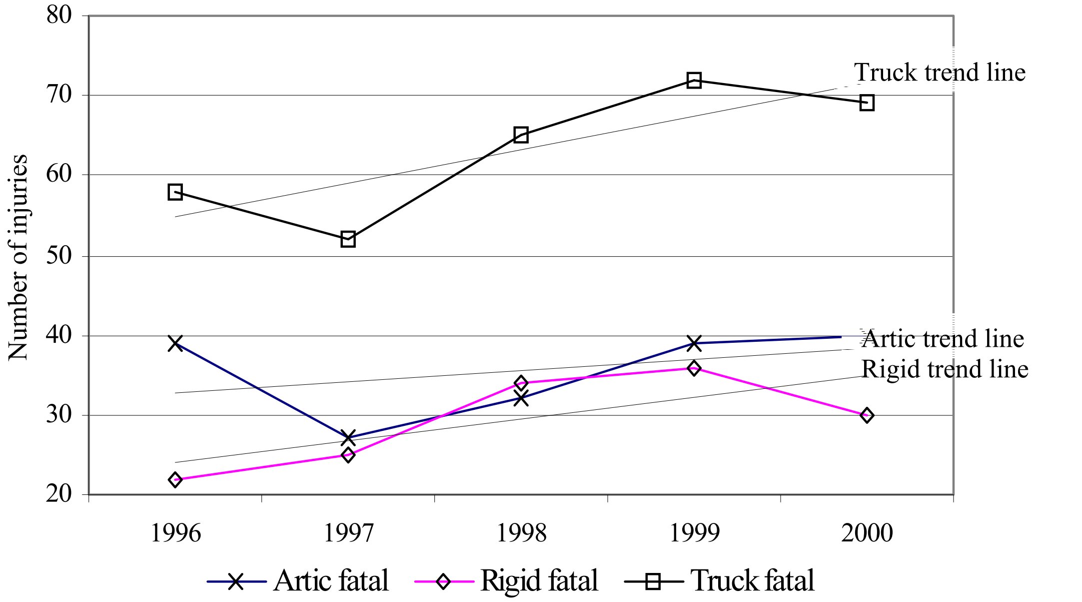


Figure 5. Yearly trend of fatalities.

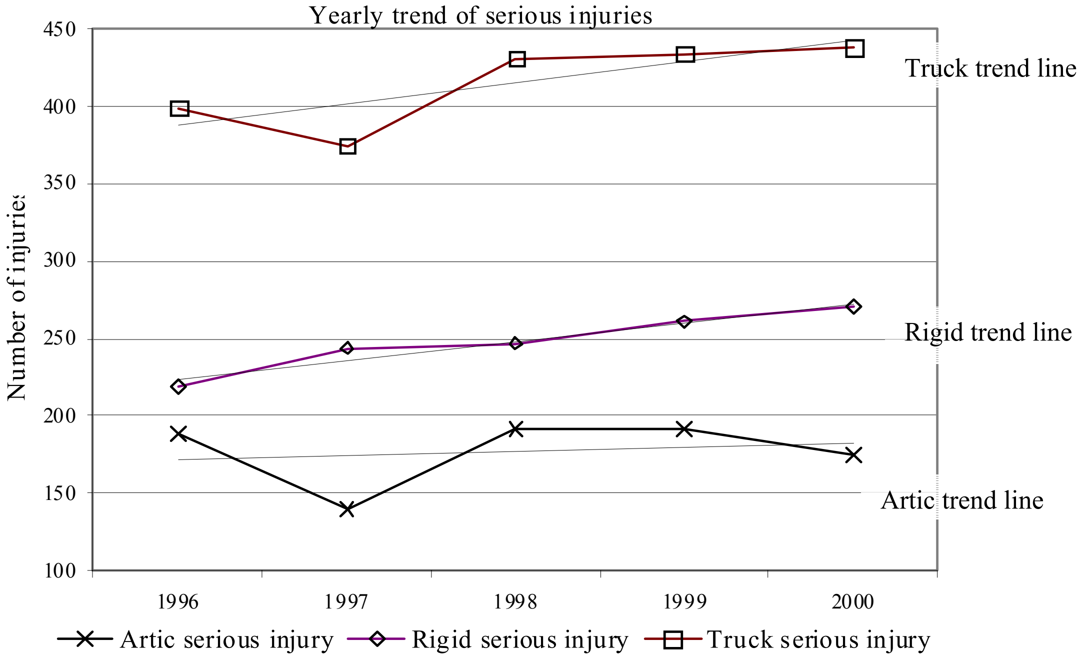


Figure 6. Yearly trend of serious injuries.

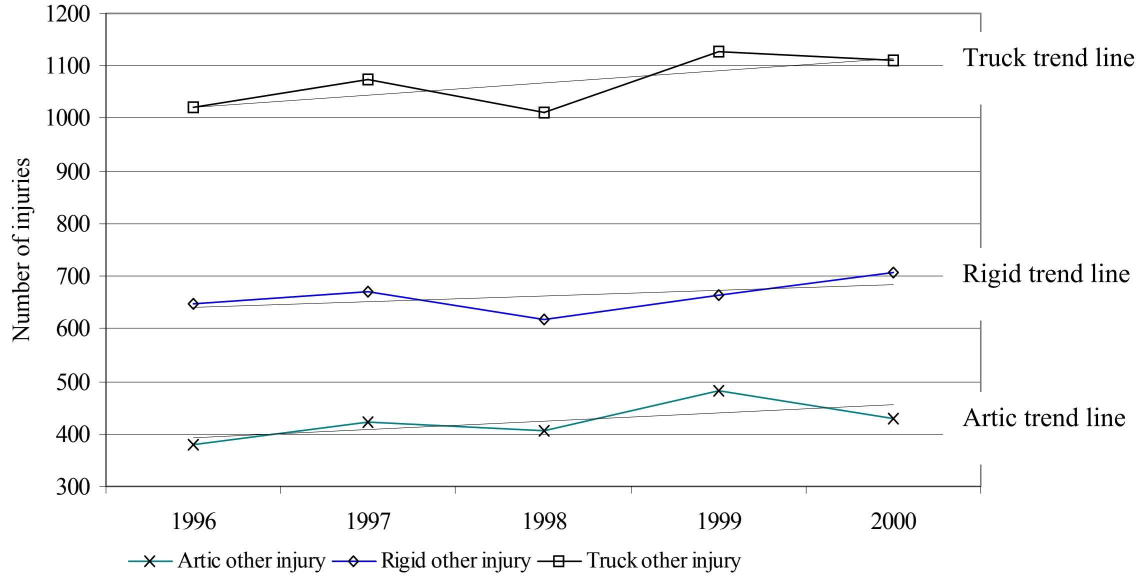


Figure 7. Yearly trend of other injuries

4.3.1 Metropolitan vs. rural areas

In a similar pattern to that revealed in the crash-based analysis earlier, there were substantially more articulated-involved fatalities in crashes in rural LGAs than in metropolitan areas (see Table 23). However, substantially more persons were involved in crashes and received other injuries and no injuries in metropolitan areas. A somewhat greater number of persons sustained serious injuries in articulated crashes in rural areas, however the difference is not as great as for the other categories of injury. For rigid truck crashes, there were more of each type of injury in metropolitan compared to rural LGAs.

Table 23. Persons injured in truck crashes in metropolitan and rural areas.

Crash	Location	Injury severity				Total
		Fatal injury	Serious injury	Other injury	Non injury	
Artic	Metro	55	486	1345	2108	**3994**
	Rural	122	400	774	801	**2097**
	Total	177	886	2119	2909	**6091**
Rigid	Metro	97	974	2688	4300	**8059**
	Rural	50	268	622	731	**1671**
	Total	147	1242	3310	5031	**9730**
Truck	Metro	150	1439	3977	6311	**11877**
	Rural	166	637	1365	1483	**3651**
	Total	316	2076	5342	7794	**15528**

4.3.2 Type of vehicle and road user

Table 24 considers the injuries in crashes involving trucks on the basis of the type of road user who was injured. Of the 316 people killed in truck crashes, 202 (64%) were car occupants, 51 (16%) were truck occupants, 19 (6%) were motorcyclists, 13 (4%) were bicyclists and 28 (9%) were pedestrians. The remainder were occupants of other vehicles. At lower levels of severity, the representation of truck occupants increased and the representation of other road users decreased.

Articulated truck crashes were more likely to result in death or serious injury to the truck occupant than rigid truck crashes. Of the 177 people killed in articulated vehicle crashes, 34 (19%) were occupants of the articulated truck and 4 (2%) were occupants of rigid trucks. Of the 147 people killed in rigid truck crashes, 17 (12%) were occupants of the rigid truck.

4.3.3 Crash type

A summary of the number of persons injured in different types of crashes (DCA categories) is presented in Tables 25 to 27. For both articulated and rigid truck crashes, the largest number of fatalities occurred where the vehicles involved were travelling in opposing directions. This category produced the second highest number of serious injuries, other injuries and non-injuries. The crash category 'vehicles travelling in the same direction' produced the highest number of non-fatal injuries.

Table 24. Injuries as a function of type of other vehicle involved in crash.

Vehicle type	Truck type	Injury Level				Total
		Fatal injury	Serious injury	Other injury	Non injury	
Car	Artic	108	547	1416	923	2994
	Rigid	97	768	2235	1805	4905
	Truck	202	1294	3636	2725	7857
Articulated truck	Artic	34	203	496	1810	2543
	Rigid		8	22	92	122
	Truck	34	203	496	1810	2543
Rigid truck	Artic	4	22	49	55	130
	Rigid	17	250	718	2950	3935
	Truck	17	250	718	2950	3935
Bus/Coach	Artic		2	30	58	90
	Rigid		3	62	79	144
	Truck		5	91	137	233
Mini bus	Artic	1		5		6
	Rigid			1	2	3
	Truck	1		6	2	9
Motor cycle	Artic	10	39	33	3	85
	Rigid	9	53	58	8	128
	Truck	19	92	91	12	214
Bicycle	Artic	5	17	24	1	47
	Rigid	8	55	88	2	153
	Truck	13	72	112	3	200
Horse	Artic		5	2		7
	Rigid		2		1	3
	Truck		7	2	1	10
Tram	Artic		3	5	13	21
	Rigid		1	14	40	55
	Truck		4	19	53	76
Train	Artic		12	15	12	39
	Rigid				2	2
	Truck		12	15	14	41
Other vehicle	Artic	1	7	19	21	48
	Rigid	1	9	12	20	42
	Truck	2	16	31	41	90
Pedestrian	Artic	14	29	22	2	67
	Rigid	15	93	98	8	214
	Truck	28	121	120	10	279
Unknown	Artic		1	3	12	16
	Rigid			2	22	24
	Truck		1	5	37	43

Table 25. Persons injured in articulated truck crashes as a function of crash type (DCA category).

DCA category	Injury Level				Total
	Fatal injury	Serious injury	Other injury	Non injury	
Pedestrian	13	24	17	56	**110**
Adjacent vehicle	28	121	199	331	**679**
Opposing direction	66	138	241	328	**773**
Same direction	23	254	1041	1643	**2961**
Manoeuvring	12	54	78	127	**271**
Overtaking	8	41	59	98	**206**
On path	2	47	83	102	**234**
Off path straight	8	92	189	106	**395**
Off path curve	15	84	172	37	**308**
Miscellaneous	2	32	40	82	**156**
Total	**177**	**887**	**2119**	**2910**	**6093**

Table 26. Persons injured in rigid truck crashes as a function of crash type (DCA category).

DCA category	Injury Level				Total
	Fatal injury	Serious injury	Other injury	Non injury	
Pedestrian	14	79	81	191	**365**
Adjacent vehicle	33	230	518	730	**1511**
Opposing direction	47	244	456	690	**1437**
Same direction	16	336	1388	2473	**4213**
Manoeuvring	10	69	239	301	**619**
Overtaking	3	33	82	120	**238**
On path	12	103	224	194	**533**
Off path straight	3	79	202	170	**454**
Off path curve	6	44	73	30	**153**
Miscellaneous	3	25	47	132	**207**
Total	**147**	**1242**	**3310**	**5031**	**9730**

Table 27. Persons injured in truck crashes as a function of crash type (DCA category).

DCA category	Injury Level				Total
	Fatal injury	Serious injury	Other injury	Non injury	
Pedestrian	26	102	97	247	**472**
Adjacent vehicle	60	345	709	1056	**2170**
Opposing direction	111	374	684	1010	**2179**
Same direction	36	564	2381	4011	**6992**
Manoeuvring	22	123	315	427	**887**
Overtaking	10	65	137	208	**420**
On path	14	149	301	290	**754**
Off path straight	11	171	389	274	**845**
Off path curve	21	128	245	67	**461**
Miscellaneous	5	56	84	205	**350**
Total	**316**	**2077**	**5342**	**7795**	**15530**

4.3.4 The truck drivers

Analyses were also conducted regarding a number of demographic details of the truck drivers involved in truck crashes. In both articulated and rigid truck crashes, the largest age group of truck drivers represented was 31 to 40 years old, followed by 41 to 50 years old (see Table 28). "Years of driving experience" is also coded by the database but around 95% of the cases are listed as "unknown", making any conclusions unreliable. There were very few female truck drivers (see Table 29).

As might be expected, the majority of truck drivers were licensed in Victoria, with NSW representing the second largest group (see Table 30). While the vast majority of trucks involved in crashes were registered in Victoria, the second most common state of registration for articulated trucks was South Australia (see Table 31).

Table 28. Age distribution of crash-involved truck drivers.

Age group	Artic	Rigid	Truck
17-20	4	57	61
21-25	165	308	459
26-30	382	480	832
31-40	760	994	1688
41-50	562	752	1264
51-60	323	512	801
61-100	79	157	224
Missing	176	199	360

Table 29. Gender distribution of crash-involved truck drivers.

	Artic	Rigid	Truck
Female	10	38	47
Male	2298	3264	5356
Unknown	143	157	286

Table 30. State of licensing of crash-involved truck drivers.

Licensing State	Artic	Rigid	Truck
Victoria	1821	3123	4774
Australian Capital Territory	8	2	10
Commonwealth	22	7	28
Northern Territory	3		3
New South Wales	175	57	214
Overseas		9	9
Queensland	68	20	85
South Australia	120	21	130
Tasmania	3		3
Western Australia	35	7	40
Not Available	10	24	33
Unknown	186	189	360

Table 31. State of registration of crash-involved trucks.

Registration State	Artic	Rigid	Truck
Victoria	1850	3215	4893
Australian Capital Territory	7	1	7
Commonwealth	41	8	45
Northern Territory	2		2
New South Wales	123	44	154
Overseas		1	1
Queensland	57	18	74
South Australia	156	25	170
Tasmania	7	1	8
Western Australia	14	4	17
Not Available	1	1	2
Unknown	193	141	316

5. POTENTIAL BENEFITS OF UNDERRUN PROTECTION

The likelihood of severe injury outcomes in collisions between trucks and smaller vehicles due to the imbalances in mass and rigidity was discussed earlier. A further source of incompatibility between trucks and smaller vehicles is the difference in ride heights. The front, sides and rear of a rigid truck or an articulated truck with a trailer are often at the same height (or higher) above the roadway as the bonnet or boot of a car. Thus, when a smaller vehicle and truck collide, significant intrusion, and therefore injury to car occupants, can result. Additionally, the car can become firmly wedged under the truck, making it more difficult to treat and extricate casualties.

Underrun protection devices on trucks are designed to engage the car safety systems and thus reduce the level of intrusion into the passenger compartment in these crashes. Some devices also crumple to absorb some of the impact energy.

Front underrun protection devices aim to reduce the severity of injury outcome of crashes in which:

- the front of the truck impacts the side of the light vehicle
- the front of the truck impacts the rear of the light vehicle
- the front of the truck impacts the front of the light vehicle

Side underrun protection devices are designed to reduce the severity of injury outcome of crashes in which:

- the front of the light vehicle impacts the side of the truck

Rear underrun protection devices are designed to reduce the severity of injury outcome of crashes in which:

- the front of the light vehicle impacts the rear of the truck

This section of the report examines the crash data to estimate the prevalence of crashes where underrun protection has the potential to reduce the severity of injury. A cost-benefit ratio for fitting all trucks with underrun protection is then estimated.

5.1 IDENTIFICATION OF POTENTIAL UNDERRUN CRASHES IN VICTORIAN DATA

The Victorian road crash database does not allow crashes in which underrun occurred to be clearly identified. However, the crash types that could potentially result in underrun can be identified using the DCA coding system. As described in Section 4.2.6, the DCA coding system provides a numerically coded description of the crash. Most of the DCA codes describe collisions between two vehicles, but other codes specify a number of ways that a pedestrian could be involved, or collisions with a stationary object or an animal, or a single vehicle leaving the path of travel.

Twenty-eight of the 81 DCA codes describe potential underrun scenarios but how many of these actually involve underrun is unknown. For example, a car may collide with the side of a semi trailer, but hit the wheels of the trailer without any underrun occurring. In addition, the specific configuration of how the vehicles collided and the point of impact often cannot be determined from the DCA coding. For this reason, the number of crashes identified as potential underrun crashes by using the DCA codes will overestimate the actual number of underrun crashes.

The crash diagrams for each of the 28 DCA codes that represent potential underrun crashes are presented in the tables which follow, along with the number of crashes that occurred. In order for the crash to have involved underrun, the truck must have been coded as a particular vehicle (i.e. vehicle 1 or vehicle 2) for each DCA code. In some types of crashes (as indicated in the tables) the truck could have been vehicle 1 or vehicle 2.

It should be noted that the crash database allows for up to four vehicles per crash to be included. However, only one DCA code is listed for the crash, and DCA codes only describe the interaction of one or two vehicles. This means that only one or two vehicles can be considered to have been involved in the primary crash, and any other vehicles involved must be considered to be subsequent to the DCA event. While any number of these subsequent vehicles may have underrun a truck that has already been involved in a crash, the data file does not allow the type of crash to be deduced. Accordingly, only the truck and the other primary vehicle are considered in these analyses.

5.1.1 Identifying crashes that could be influenced by front underrun protection

As noted earlier, front underrun protection devices are designed to reduce the severity of injury outcome in crashes in which the front of the truck impacts the side, rear or front of the light vehicle.

Table 32 summarises the 11 DCA codes that describe crashes where the front of a truck appears to have collided with the rear of another vehicle. There were 1,045 crashes of this type. The most common scenario was where a truck collided with the back of another vehicle while both vehicles were travelling in the same direction (DCA code 130), a total of 630 crashes, or 60% of the total for this category.

Table 33 summarises the three DCA codes that describe crashes where a truck collided with the front of another vehicle – head-on crashes. Of these 354 crashes, 98% (or 346 crashes) occurred where one of the vehicles was travelling on the wrong side of the road and neither vehicle was overtaking.

Table 34 summarises the nine DCA codes that describe crashes where the front of a truck has collided with the side of another vehicle. There were 936 instances of this type of crash, with 309 crashes (33%) where the vehicles approached each other at right angles at a cross intersection (DCA code 110). However, it should be noted that in DCA 110 the crash could involve the front of the truck impacting the side of another vehicle (addressed by front underrun protection) or the front of the other vehicle impacting the side of the truck (addressed by side impact protection) and the truck could be either vehicle 1 or vehicle 2 in the crash. As such, these 309 crashes are listed here as well as being included in the potential side underrun crashes (see Table 36). The actual configuration of the particular crash depends on which vehicle entered the intersection first but the crash database does not allow this distinction to be made.

Table 32. Crashes potentially addressed by front underrun protection – involving the front of the truck and the rear of a light vehicle as identified by DCA code.

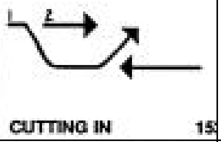
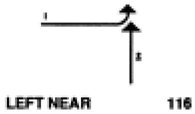
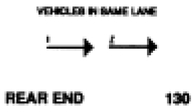
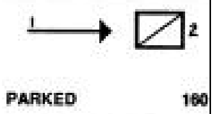
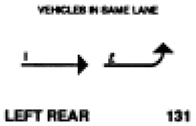
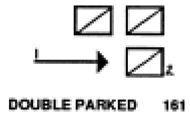
DCA code	Crash configuration	Total crashes	DCA code	Crash configuration	Total crashes
111 (truck=veh 1)		33	153 (truck=veh 2)		7
116 (truck=veh 2)		24	154 (truck=veh 1)		15
130 (truck=veh 1)		630	160 (truck=veh 1 or 2)		69
131 (truck=veh 1)		97	161 (truck=veh 1)		2
132 (truck=veh 1)		152	162 (truck=veh 1)		11
145 (truck=veh 2)		5			

Table 33. Crashes potentially addressed by front underrun protection – crashes involving the front of the truck and the front of the light vehicle as identified by DCA code.

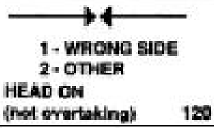
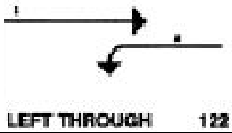
DCA code	Crash configuration	Total crashes	DCA code	Crash configuration	Total crashes
120 (truck=veh 1 or 2)		346	150 (truck=veh 1 or 2)		8
122 (truck=veh 1)		0			

Table 34. Crashes potentially addressed by front underrun protection – involving the front of the truck and the side of the light vehicle as identified by DCA code.

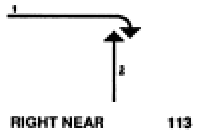
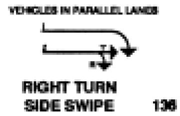
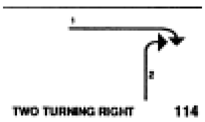
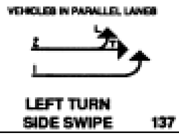
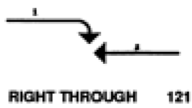
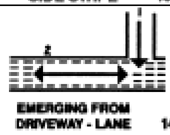
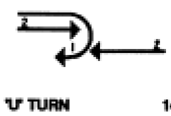
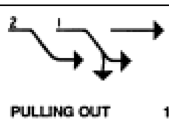
DCA code	Crash configuration	Total crashes	DCA code	Crash configuration	Total crashes
110 (truck=veh 1 or 2)		309	135 (truck=veh 1)		159
113 (truck=veh 2)		119	136 (truck=veh 2)		25
114 (truck=veh 2)		3	137 (truck=veh 2)		69
121 (truck=veh 2)		154	147 (truck=veh 2)		49
134 (truck=veh 1)		49			

Table 35 summarises the four DCA codes that describe crash configurations where a truck has collided with the side or rear of another vehicle. There were 110 of these crashes, 64% of which involved a truck hitting another vehicle as that vehicle was making a U-turn. As in the other three types of this category of crash, whether it was a side or rear underrun depends on the stage in the manoeuvre at which the crash occurred.

Table 35. Crashes potentially addressed by front underrun protection – involving the front of the truck and the side or rear of the light vehicle as identified by DCA code.

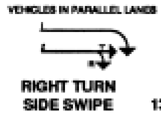
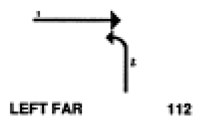
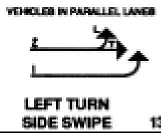
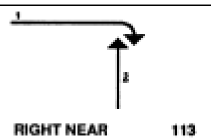
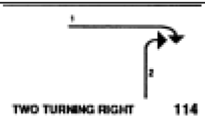
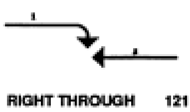
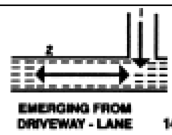
DCA code	Crash configuration	Total crashes	DCA code	Crash configuration	Total crashes
140 (truck=veh 2)		70	143 (truck=veh 2)		2
142 (truck=veh 2)		5	152 (truck=veh 2)		33

5.1.2 Identifying crashes that could be influenced by side underrun protection

As noted earlier, side underrun protection devices are designed to reduce the severity of injury outcome in crashes in which the front of the light vehicle impacts the side of the truck.

Table 36 summarises the 14 DCA codes that describe crashes where another vehicle has collided with the side of a truck. Again, DCA 110 (the cross intersection crash) is the most common of the 986 crashes in this category (309 crashes, or 31%).

Table 36. Crashes potentially addressed by side underrun protection – involving the side of the truck and the front of the light vehicle as identified by DCA code.

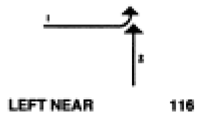
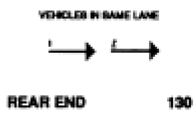
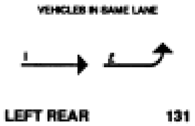
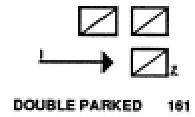
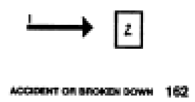
DCA code	Crash configuration	Total crashes	DCA code	Crash configuration	Total crashes
110 (truck=veh 1 or 2		309	136 (truck=veh 1)		22
112 (truck=veh 1)		4	137 (truck=veh 1)		42
113 (truck=veh 1)		150	140 (truck=veh 1)		48
114 (truck=veh 1)		1	142 (truck=veh 1)		2
121 (truck=veh 1)		165	143 (truck=veh 1)		10
134 (truck=veh 2)		104	147 (truck=veh 1)		64
135 (truck=veh 2)		49	152 (truck=veh 1)		16

5.1.3 Identifying crashes that could be influenced by rear underrun protection

Rear underrun protection devices are designed to reduce the severity of injury outcome of crashes in which the front of the light vehicle impacts the rear of the truck.

Table 37 summarises the ten DCA codes that describe crashes where another vehicle collided with the rear of a truck. Of these 432 crashes, 218 (51%) occurred when the light vehicle was travelling in the same lane behind the truck and the light vehicle collided with the rear of the truck.

Table 37. Crashes potentially addressed by rear underrun protection – involving the rear of the truck and the front of the light vehicle as identified by DCA code.

DCA code	Crash configuration	Total crashes	DCA code	Crash configuration	Total crashes
116 (truck=veh 1)		22	142 (truck=veh 1)		2
130 (truck=veh 2)		218	145 (truck=veh 1)		35
131 (truck=veh 2)		28	152 (truck=veh 1)		16
132 (truck=veh 2)		50	161 (truck=veh 2)		0
140 (truck=veh 1)		48	162 (truck=veh 2)		13

5.1.4 Summary

The analyses presented have identified a total of 3,488 crashes that could have involved an underrun of any configuration. Table 38 provides a summary of the number of crashes of each DCA type, while Table 39 summarises the crashes according to the type of underrun crash. Table 39 shows that front underrun protection is relevant to a larger number of crashes than side underrun, and rear underrun is relevant to the smallest number of crashes. The actual number of potential underrun crashes to which each type of protection is relevant cannot be clearly estimated because for 309 crashes it is unclear whether front or side underrun protection is relevant and for 66 crashes it is unclear whether side or rear underrun protection is relevant.

A total of 3,488 separate crashes occurred between either a rigid or articulated truck and another vehicle (but not another truck), where the crash could have involved underrun. Table 40 summarises the numbers of each crash severity type, categorised by truck type – articulated and rigid trucks.

Fatal crashes are most likely to occur in frontal impacts between cars and trucks. Indeed, more fatal crashes arise from any sort of crash involving the front of a truck than a car running under the rear or side of the truck. Serious injuries, however, follow a different pattern.

Serious injuries, however, follow a different pattern. Light vehicles running into the side of rigid trucks produces the highest number of serious injury crashes, followed by rigid trucks running into the side of lighter vehicles and then rigid trucks hitting the rear of lighter vehicles. In terms of other injuries, rigid trucks running into the rear of lighter vehicles is the most common, followed by light vehicles running into the side of rigid trucks and then articulated trucks striking the rear of a lighter vehicle.

Table 38. Total number of potential underrun crashes summarised by crash type (DCA code).

DCA code	Number	Percent	DCA code	Number	Percent
110	309	8.7	136	47	1.3
111	33	0.9	137	111	3.1
112	4	0.2	140	118	3.3
113	269	7.6	142	7	0.2
114	4	0.1	143	12	0.3
116	46	1.3	145	40	1.1
120	346	9.8	147	113	3.2
121	319	9.0	150	8	0.2
122	0	0.0	152	49	1.4
130	848	24.0	153	7	0.2
131	125	3.5	154	15	0.4
132	202	5.7	160	69	2.0
134	153	4.3	161	2	0.1
135	208	5.9	162	24	0.7
	Total			**3488**	

Table 39. Number of potential underrun crashes summarised by crash scenario.

Type of underrun protection relevant	Crash type	Number
Front	truck into rear of another vehicle	1045
	truck into front of another vehicle	354
	truck into side of another vehicle	936 (includes 309 crashes that could belong to side underrun)
	truck into side or rear of another vehicle	110
Side	another vehicle into side of truck	986 (includes 309 crashes that could belong to front underrun and 66 crashes that could belong to rear underrun)
Rear	another vehicle into rear of truck	432 (includes 66 crashes that could belong to side underrun)
	Total	3,488

Table 40. Number of potential underrun crashes. Victoria 1996-2000. Adjusted for double counting.

Type of protection relevant	Type of crash	Crash severity		
		Fatal	Serious injury	Other injury
ARTICULATED TRUCKS				
Front underrun	Truck into rear of light vehicle	4	65	308
	Truck into front of light vehicle	42	41	58
	Truck into side	21.5	96	231
	Truck into side or rear of light vehicle	6	24	18
	Total front underrun	**73.5**	**226**	**615**
Side underrun	**Light vehicle into side of truck**	**16.5**	**86**	**170.5**
Rear underrun	**Light vehicle into rear of truck**	**3**	**50**	**82.5**
RIGID TRUCKS				
Front underrun	Truck into rear of light vehicle	5	118	545
	Truck into front of light vehicle	30	90	93
	Truck into side	24.5	126	282.5
	Truck into side or rear of light vehicle	4	17	41
	Total front underrun	**63.5**	**351**	**961.5**
Side underrun	**Light vehicle into side of truck**	**19.5**	**149**	**357**
Rear underrun	**Light vehicle into rear of truck**	**7**	**83**	**180.5**
ALL TRUCKS				
Front underrun	Truck into rear of light vehicle	9	183	853
	Truck into front of light vehicle	72	131	151
	Truck into side	46	223	513.5
	Truck into side or rear of light vehicle	10	41	59
	Total front underrun	**137**	**578**	**1576.5**
Side underrun	**Light vehicle into side of truck**	**36**	**236**	**525.5**
Rear underrun	**Light vehicle into rear of truck**	**10**	**126**	**263**

5.2 ESTIMATE OF NUMBER OF UNDERRUN CRASHES AUSTRALIA-WIDE

In 1992, 1994 and 1996, 20% of Australia's fatal articulated truck crashes and 17% of Australia's fatal rigid truck crashes occurred in Victoria (see Table 2). Similar information is not available for truck crashes resulting in serious injury or other injury. If it is assumed that the distribution of serious injury or other injury crashes is similar to that of fatal crashes, and if it is assumed that the distribution of underrun crashes follows that of all truck crashes, then it is possible to estimate the number of underrun crashes Australia-wide by extrapolating from the Victorian data. The results of this estimation are presented in Table 41.

Table 41. Estimate of annual number of potential underrun crashes as a function of injury severity. Australia.

Type of protection relevant	Crash severity		
	Fatal	Serious injury	Other injury
ARTICULATED TRUCKS			
Front underrun	73.5	226.0	615.0
Side underrun	16.5	86.0	170.5
Rear underrun	3.0	50.0	82.5
RIGID TRUCKS			
Front underrun	74.7	412.9	1131.2
Side underrun	22.9	175.3	420.0
Rear underrun	8.2	97.6	212.4
ALL TRUCKS			
Front underrun	148.2	638.9	1746.2
Side underrun	39.4	261.3	590.5
Rear underrun	11.2	147.6	294.9

5.3 COST OF UNDERRUN CRASHES

There are no published estimates of the costs of underrun crashes. In terms of the costs of truck crashes overall, Cairney (1991) concluded that the average costs of truck crashes involving injuries were approximately double those of casualty crashes that did not involve a truck. He states that “it is recommended that road authorities adopt these weighting factors when assessing the need for safety-related improvements” (Cairney, 1991, p.14). In developing their submission to the Neville Inquiry, the Australian Transport Safety Bureau (ATSB) assumed that the average heavy vehicle crash costs 50% more than other crashes at the same severity level. They note that this assumption was arbitrary, but probably conservative.

If the ATSB approach is taken, then the cost of heavy vehicle crashes can be estimated as

fatal crash $2,479,491

serious injury crash $611,985

other injury crash $20,664

In Table 42, the annual costs of underrun crashes in Australia are estimated using these crash costs and assuming that half of the potential underrun crashes actually involve underrrun. The table shows that the estimated annual total cost of underrun crashes in Australia is approximately $594 million. Front underrun crashes account for almost two-thirds of this amount.

Table 42. Estimated annual cost ($000s) of estimated number of underrun crashes (number of potential crashes divided by 2) involving a lighter vehicle in Australia. Based on estimates of crashes Australia-wide 1996-2000 and BTE (2000) crash costs times 1.5.

Type of protection relevant	Crash severity			
	Fatal	Serious injury	Other injury	Total
ARTICULATED TRUCKS				
Front underrun	91,121,294	69,154,305	6,354,180	166,629,779
Side underrun	20,455,801	26,315,355	1,761,606	48,532,762
Rear underrun	3,719,237	15,299,625	852,390	19,871,252
Total	115,296,332	110,769,285	8,968,176	235,033,793
RIGID TRUCKS				
Front underrun	92,616,281	126,356,903	11,687,315	230,660,500
Side underrun	28,441,220	53,638,685	4,339,440	86,419,346
Rear underrun	10,209,669	29,879,268	2,194,031	42,282,967
Total	131,267,171	209,874,856	18,220,786	359,362,812
ALL TRUCKS				
Front underrun	183,737,576	195,511,208	18,041,495	397,290,279
Side underrun	48,897,021	79,954,040	6,101,046	134,952,107
Rear underrun	13,928,905	45,178,893	3,046,421	62,154,219
Total	246,563,502	320,644,141	27,188,962	594,396,605

Using the same cost for articulated and rigid truck crashes may not be appropriate, given that the cost of the cargo is likely to be higher for an articulated truck. However, in many underrun crashes there is little damage to the truck and cargo.

5.4 EFFECTIVENESS OF UNDERRUN PROTECTION DEVICES

Rechnitzer (1993) and Rechnitzer and Foong (1991) reviewed a number of studies of the likely effectiveness of underrun protection devices. Rechnitzer and Foong (1991) cite a Swedish study showing that the introduction of rear underrun devices (in conjunction with improvements in occupant restraint and improved rear visibility of trucks) led to a reduction in fatalities due to underrun crashes from 13% to about 3%. They also cite a

British study by Riley et al (1981) which found that 20 of the 55 fatalities in rear underrun crashes could have been prevented by having an appropriate guard (this assumes survivability at 60 km/h of restrained occupants). Based on these and a number of other studies, they estimated the reductions in fatalities and injury severity resulting from improved frontal and side design of trucks. These reductions are summarised in Table 43.

Table 43. Estimates from Rechnitzer (1993) Table 5.8. of the reductions in fatalities and injury severity resulting from improved frontal and side design of trucks.

Crash type	Expected reduction in fatalities	Estimated reduction in injury severity for injury cases
Car-truck	15+%	30%
Pedestrian-truck	20%	25+%
Two wheeler-truck	20+%	25+%
Total	16%	28%

Rigid rear underrun systems are highly effective for speeds up to 60-70 km/h as they then engage the car's safety systems. Energy absorbing rear underrun systems are effective at speeds up to 70-90 km/h for airbag-equipped cars. An English study estimated that rear underrun systems would prevent about 35% of fatalities in rear underrun crashes (Riley et al, 1981, cited in Rechnitzer and Foong, 1991).

Rechnitzer and Foong (1991) state that "the current ADR regulations (ADR 42.6 Rear Bumper for Semi-Trailers), only applies to a very limited range of vehicles, and is known to be inadequate. Common deficiencies found on rear guard designs are inadequate bracing and connection design and execution, and incorrect height, with the potential load resistance being wasted by inadequate design and detailing. It is evident that many of these barriers could be redesigned and substantially upgraded in capacity, with little penalty in the way of cost or weight increase, above what is already being incurred" (p.22).

5.5 ESTIMATED BENEFITS OF UNDERRUN PROTECTION DEVICES

Underrun protection will not prevent crashes. In most instances, it will save lives and reduce the extent of injury but in many cases, some level of injury will still occur. The actual reduction in the cost of property damage is likely to be small, compared to the benefits in terms of the savings in lives and long-term injuries.

The analysis presented here will assume that:

- front underrun protection will change 15% of fatal crashes to serious injury crashes and 30% of serious injury crashes to other injury crashes
- side underrun protection will change 15% of fatal crashes to serious injury crashes and 30% of serious injury crashes to other injury crashes

- rear underrun protection will change 30% of fatal crashes to serious injury crashes and 30% of serious injury crashes to other crashes

5.6 COST OF UNDERRUN PROTECTION DEVICES

Effective rigid rear underrun systems do not require significantly more material or work than is currently used. The cost varies from about $200 to $500. Energy absorbing rear underrun systems would work at speeds up to 70-90 km/h for airbag-equipped cars and would cost roughly $1,000 to $1,500. Costs could be somewhat less with good commercial design development.

Front underrun systems as used in Europe comprise a simple steel beam with a cost of about $100 to $150. Discussions with one European manufacturer found that they did not regard the front underrun protection to be any additional cost as they used it to support other components.

5.7 CALCULATION OF ESTIMATED BENEFIT:COST RATIOS

Benefit:Cost Ratios (BCRs) were estimated for the following scenarios:

- A package of front, side and rear underrun costing $500
- A package of front, side and rear underrun costing $1,000
- Front underrun protection costing $100
- Front underrun protection costing $200
- Side underrun protection costing $200
- Rear underrun protection costing $200

The number of trucks to which these costs should be applied was taken from the numbers of articulated and rigid trucks in the Survey of Motor Vehicle Use. The ABS Survey of Motor Vehicle Use for the 12 months ending 31 October 2000 (ABS, 2001) estimated there were 341,484 rigid trucks and 59,989 articulated trucks in Australia. Some of these trucks will already have adequate underrun protection fitted, but it was assumed that this would reduce both benefits and costs in a similar manner, and therefore the benefit:cost ratios would not be affected.

The calculations assumed a 7% discount rate with lifetimes of 15 years or 25 years.

The BCR calculations are presented in Appendix 1 and are summarised in Tables 44 and 45. For all of the underrun protection measures included, the BCRs were higher for articulated trucks than rigid trucks. The BCRs were higher when a 15-year lifetime was assumed, than when a 25-year lifetime was assumed.

A package of front, side and rear underrun had a BCR of greater than 1 for both articulated trucks and rigid trucks, whether a 17- or 25- year lifetime is assumed. Not surprisingly, the BCR was doubled if the package cost $500, compared to if the package cost $1,000.

The BCRs also exceeded 1 for each type of underrun protection – front (at a cost of either $100 or $200), side or rear – for both articulated trucks and rigid trucks; again regardless of the lifetime. The BCRs were considerably larger for front underrun protection than for side underrun protection, with the lowest BCRs found for rear underrun protection.

Table 44. Summary of benefit:cost ratios for a range of underrun protection measures. Assumes discount rate of 7% and 15 year lifetime.

Type of measure	Articulated trucks	Rigid trucks	All trucks
Package ($500)	16.5	4.9	6.6
Package ($1,000)	8.2	2.5	3.3
Front underrun ($100)	54.9	15.0	21.0
Front underrun ($200)	27.5	7.5	10.5
Side underrun	9.0	3.0	3.9
Rear underrun	4.8	1.8	2.2

Table 45. Summary of benefit:cost ratios for a range of underrun protection measures. Assumes discount rate of 7% and 25 year lifetime.

Type of measure	Articulated trucks	Rigid trucks	All trucks
Package ($500)	13.3	4.0	5.4
Package ($1,000)	6.6	2.0	2.7
Front underrun ($100)	44.2	12.1	16.9
Front underrun ($200)	22.1	6.1	5.1
Side underrun	7.2	2.4	3.1
Rear underrun	3.8	1.4	1.8

6. SUMMARY AND CONCLUSIONS

This report presents an updated statistical profile of the characteristics of heavy vehicle crashes in Victoria and then uses this as a basis for estimating the benefits of the recommended design improvements arising from the Stage 1 report on Underrun Protection.

6.1 NATIONAL COMPARISONS

Truck crash data vary in their availability, scope and timeliness. Basic timely data are available nationally for fatal articulated truck crashes but not for rigid truck crashes. Statewide crash data are available for articulated and rigid truck crashes that result in injury, although delays in finalising data can occur. Estimates of the amount of travel in particular jurisdictions can be difficult to obtain and therefore jurisdiction-wide crash rates are not available for all years.

The number of truck crashes appears to be increasing. From 1991 to 1997, the number of fatal articulated vehicle crashes in Victoria and Australia was reasonably constant. Since 1997, the number of fatal crashes appears to have increased Australia-wide. In Victoria, the number of both rigid and articulated truck crashes has been steadily increasing between 1996 and 2000, with rigid truck crashes increasing at a slightly higher rate.

In 1997, the fatality rates for articulated and rigid trucks (both in terms of registered vehicles and in terms of distance travelled) were lower in Victoria than for Australia as a whole.

Australia-wide and in Victoria, fatality rates are higher for articulated than rigid trucks regardless of whether registered vehicles or distance travelled is used as the denominator.

The fatal truck crashes in Victoria and the rest of Australia in 1992, 1994 and 1996 were similar in terms of mixture of crash types (single truck only, truck-pedestrian, and multiple-vehicle), divided and undivided roads and day and night-time crashes. In Victoria, relatively more fatal truck crashes occurred in the capital city and in rural areas and relatively fewer occurred in other urban areas compared to other States and Territories.

6.2 TRUCK CRASHES IN VICTORIA 1996-2000

From 1996-2000 there were 5,622 reported truck crashes in Victoria, of which 282 were fatal, 1,656 resulted in serious injury and 3,684 resulted in other injury. About 40% of truck crashes involved articulated trucks and 60% involved rigid trucks. A higher proportion of articulated truck crashes resulted in fatalities compared with rigid truck crashes – 7% versus 4% respectively.

Overall, 316 people were killed, 2,077 were seriously injured and 5,342 sustained some other injury in truck crashes in Victoria in 1996-2000. Of those killed, 177 were involved in articulated truck crashes and 147 were involved in rigid truck crashes.

Of the people killed in truck crashes, 64% were car occupants, 16% were truck occupants, 9% were pedestrians, 6% were motorcyclists and 4% were bicyclists. At lower levels of severity, the representation of truck occupants increased and the representation of other road users decreased.

Articulated truck crashes were more likely to result in death or serious injury to the truck occupant than rigid truck crashes. Almost 20% of people killed in articulated vehicle crashes were occupants of the articulated truck and an additional 2% were occupants of rigid trucks involved in collisions with articulated trucks. Of the people killed in rigid truck crashes, 12% were occupants of the rigid truck.

About 80% of the crashes occurred during daylight hours (a lower proportion for articulated than rigid truck crashes), possibly reflecting their pattern of use. Night-time crashes were generally more severe than daytime crashes. This may reflect higher travel speeds at night because of less traffic congestion.

About three-quarters of the crashes occurred in metropolitan areas, although the proportion was lower for articulated than rigid truck crashes. Fatal crashes involving articulated trucks were more common in rural areas than in the metropolitan area. Articulated truck crashes were more likely to have occurred in higher speed zones than rigid truck crashes. For trucks overall, low speed areas had the highest number of injury crashes, followed by high speed areas and then mid-speed areas. The proportion of crashes resulting in death or serious injury increased with speed zone. In low speed zones and high speed zones, articulated truck crashes were more likely to be fatal than rigid truck crashes.

About half of the crashes occurred at intersections (a lower proportion for articulated than rigid truck crashes). In the metropolitan area, similar proportions of articulated and rigid truck crashes occurred at intersections.

The most common type of crash for both articulated and rigid trucks involved vehicles travelling in the same direction. For both articulated and rigid trucks, the largest number of fatal crashes involved a collision between vehicles travelling in opposing directions – 'head-on' crashes. Same direction crashes were the most common type of serious injury and other injury crash for both articulated and rigid trucks.

A traffic control device was present in 32% of metropolitan crashes and 17% of rural crashes. In metropolitan areas, traffic control devices were equally common at the sites of articulated and rigid truck crashes. In rural areas, traffic control devices were more likely to be found at the sites of rigid truck crashes than articulated truck crashes. Stop-go lights were the most traffic control devices at the sites of truck crashes in metropolitan areas. For articulated truck crashes in rural areas, the most likely traffic control device present was a give-way sign. For rigid truck crashes in rural areas, stop signs were the most likely traffic control present.

Most of the truck crashes at stop-go lights in metropolitan areas involved vehicles travelling in the same direction. About 20% of these crashes involved adjacent vehicles and about another 20% involved vehicles from opposing directions. The bulk of truck crashes in metropolitan areas that occurred at stop and give way signs involved adjacent vehicles. For truck crashes at give-way signs in rural areas, the most likely crash category was "adjacent vehicle".

The most common age group of truck drivers in crashes was 31 to 40 years old, followed by 41 to 50 years old. "Years of driving experience"was missing from the database for most drivers. There were very few female truck drivers. The majority of truck drivers were licensed in Victoria, with NSW representing the second largest group. While the vast majority of trucks involved in crashes were registered in Victoria, the second most common state of registration for articulated trucks was South Australia.

6.3 POTENTIAL BENEFITS OF UNDERRUN PROTECTION

The Victorian road crash database does not allow crashes in which underrun occurred to be clearly identified. However, crash types that could potentially result in underrun can be identified using the DCA coding system, which provides a numerically coded description of the crash. The number of crashes identified as potential underrun crashes by using the DCA codes will overestimate the actual number of underrun crashes.

During the period 1996-2000 inclusive, a total of 3,488 separate crashes occurred between either a rigid or articulated truck another vehicle (but not another truck). The three most common types of crashes involved rigid trucks – a rigid truck hitting the rear of a lighter vehicle, followed by a lighter vehicle striking the side of a rigid truck and then a rigid truck running into the side of a lighter vehicle. The fourth, fifth and sixth most common types of crashes involved articulated trucks and followed a different pattern – an articulated truck hitting the rear of a light vehicle, followed by an articulated truck running into the side of a lighter vehicle, and then a lighter vehicle striking the side of an articulated truck.

Frontal impacts were less common types of crashes, but were most likely to be fatal crashes for both articulated and rigid trucks. Indeed, more fatal crashes arise from any sort of crash involving the front of a truck than a lighter vehicle running under the rear or side of the truck. Serious injuries, however, follow a different pattern. Light vehicles running into the side of rigid trucks produces the highest number of serious injury crashes, followed by rigid trucks running into the side of lighter vehicles and then rigid trucks hitting the rear of lighter vehicles. In terms of other injuries, rigid trucks running into the rear of lighter vehicles is the most common, followed by light vehicles running into the side of rigid trucks and then articulated trucks striking the rear of a lighter vehicle.

The analysis presented here assumed that:

- the number and severity of underrun crashes Australia-wide can be extrapolated from the Victorian data
- half of the potential underrun crashes identified in the crash data actually involved underrun
- the average heavy vehicle crash costs 50% more than other crashes at the same severity level
- underrun protection is to be fitted to all rigid and articulated trucks
- front underrun protection will change 15% of fatal crashes to serious injury crashes and 30% of serious injury crashes to other injury crashes
- side underrun protection will change 15% of fatal crashes to serious injury crashes and 30% of serious injury crashes to other injury crashes
- rear underrun protection will change 30% of fatal crashes to serious injury crashes and 30% of serious injury crashes to other crashes

Benefit:cost ratios (BCRs) were estimated for the following scenarios:

- A package of front, side and rear underrun costing $500 per vehicle
- A package of front, side and rear underrun costing $1,000 per vehicle
- Front underrun protection costing $100 per vehicle
- Front underrun protection costing $200 per vehicle
- Side underrun protection costing $200 per vehicle
- Rear underrun protection costing $200 per vehicle

For all of the underrun protection measures included, the BCRs were higher for articulated trucks than rigid trucks. The BCRs were higher when a 15-year lifetime was assumed, than when a 25-year lifetime was assumed.

A package of front, side and rear underrun had a BCR of greater than 1 for both articulated trucks and rigid trucks, whether a 17- or 25- year lifetime is assumed. Not surprisingly, the BCR was doubled if the package cost $500, compared to if the package cost $1,000.

The BCRs also exceeded 1 for each type of underrun protection – front (at a cost of either $100 or $200), side or rear – for both articulated trucks and rigid trucks; again regardless of the lifetime. The BCRs were considerably larger for front underrun protection than for side underrun protection, with the lowest BCRs found for rear underrun protection.

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APPENDIX 1: CALCULATIONS OF BENEFIT:COST RATIOS

Underrun protection package						
Cost Package 1=$500 Package 2=$1000	Discount 7% and 15 years=0.362 Discount 7% and 25 years=0.175					
Lifetime 15yrs	Crash cost saving	Discount	Benefit	No. vehs	Cost	BCR
PACKAGE 1, artics	1366643.2	0.362	494724.8	60,000	30000	16.5
PACKAGE 1, rigids	2304604.5	0.362	834266.8	340,000	170000	4.9
PACKAGE 1, all trucks	3671247.7	0.362	1328991.7	400,000	200000	6.6
PACKAGE 2, artics	1366643.2	0.362	494724.8	60,000	60000	8.2
PACKAGE 2, rigids	2304604.5	0.362	834266.8	340,000	340000	2.5
PACKAGE 2, all trucks	3671247.7	0.362	1328991.7	400,000	400000	3.3
Lifetime 25yrs	Crash cost saving	Discount	Benefit	No. vehs	Cost	BCR
PACKAGE 1, artics	2277738.7	0.175	398604.3	60,000	30000	13.3
PACKAGE 1, rigids	3841007.5	0.175	672176.3	340,000	170000	4.0
PACKAGE 1, all trucks	6118746.2	0.175	1070780.6	400,000	200000	5.4
PACKAGE 2, artics	2277738.7	0.175	398604.3	60,000	60000	6.6
PACKAGE 2, rigids	3841007.5	0.175	672176.3	340,000	340000	2.0
PACKAGE 2, all trucks	6118746.2	0.175	1070780.6	400,000	400000	2.7

Rear underrun protection						
Cost=$200	Discount 7% and 15 years=0.362 Discount 7% and 25 years=0.175					
Lifetime 15yrs	Crash cost saving	Discount	Benefit	No. vehs	Cost	BCR
artics	158258.6	0.362	57289.6	60,000	12000	4.8
rigids	329041.0	0.362	119112.8	340,000	68000	1.8
all trucks	487299.5	0.362	176402.4	400,000	80000	2.2
Lifetime 25yrs	Crash cost saving	Discount	Benefit	No. vehs	Cost	BCR
artics	263764.3	0.175	46158.7	60,000	12000	3.8
rigids	548401.6	0.175	95970.3	340,000	68000	1.4
all trucks	812165.9	0.175	142129.0	400,000	80000	1.8

Side underrun protection						
Cost = $200	Discount 7% and 15 years=0.362					
	Discount 7% and 25 years=0.175					
Lifetime 15yrs	Crash cost saving	Discount	Benefit	No. vehs	Cost	BCR
artics	298172.4	0.362	107938.4	60,000	12000	9.0
rigids	562844.2	0.362	203749.6	340,000	68000	3.0
all trucks	861016.6	0.362	311688.0	400,000	80000	3.9
Lifetime 25yrs	Crash cost saving	Discount	Benefit	No. vehs	Cost	BCR
artics	496954.0	0.175	86966.9	60,000	12000	7.2
rigids	938073.6	0.175	164162.9	340,000	68000	2.4
all trucks	1435027.6	0.175	251129.8	400,000	80000	3.1

Front underrun protection						
Cost = $200	Discount 7% and 15 years=0.362					
	Discount 7% and 25 years=0.175					
Lifetime 15yrs	Crash cost saving	Discount	Benefit	No. vehs	Cost	BCR
artics	910212.3	0.362	329496.8	60,000	12000	27.5
rigids	1412719.3	0.362	511404.4	340,000	68000	7.5
all trucks	2322931.6	0.362	840901.2	400,000	80000	10.5
Lifetime 25yrs	Crash cost saving	Discount	Benefit	No. vehs	Cost	BCR
artics	1517020.4	0.175	265478.6	60,000	12000	22.1
rigids	2354532.2	0.175	412043.1	340,000	68000	6.1
all trucks	2322931.6	0.175	406513.0	400,000	80000	5.1

Front underrun protection						
Cost = $100	Discount 7% and 15 years=0.362					
	Discount 7% and 25 years=0.175					
Lifetime 15yrs	Crash cost saving	Discount	Benefit	No. vehs	Cost	BCR
artics	910212.3	0.362	329496.8	60,000	6000	54.9
rigids	1412719.3	0.362	511404.4	340,000	34000	15.0
all trucks	2322931.6	0.362	840901.2	400,000	40000	21.0
Lifetime 25yrs	Crash cost saving	Discount	Benefit	No. vehs	Cost	BCR
artics	1517020.4	0.175	265478.6	60,000	6000	44.2
rigids	2354532.2	0.175	412043.1	340,000	34000	12.1
all trucks	3871552.7	0.175	677521.7	400,000	40000	16.9