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AUSTROADS TECHNICAL REPORT

Safety Benefits of Improving Interaction between Heavy Vehicles and the Road System

Austroads
promoting improved road transport outcomes

Safety Benefits of Improving Interaction between Heavy Vehicles and the Road System

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Safety Benefits of Improving Interaction between Heavy Vehicles and the Road System

Austroads

Sydney 2008

Austroads profile

Austroads' purpose is to contribute to improved Australian and New Zealand transport outcomes by:

- providing expert advice to SCOT and ATC on road and road transport issues
- facilitating collaboration between road agencies
- promoting harmonisation, consistency and uniformity in road and related operations
- undertaking strategic research on behalf of road agencies and communicating outcomes
- promoting improved and consistent practice by road agencies.

Austroads membership

Austroads membership comprises the six state and two territory road transport and traffic authorities, the Commonwealth Department of Infrastructure, Transport, Regional Development and Local Government, the Australian Local Government Association, and NZ Transport Agency. Austroads is governed by a council consisting of the chief executive officer (or an alternative senior executive officer) of each of its eleven member organisations:

- Roads and Traffic Authority New South Wales
- Roads Corporation Victoria
- Department of Main Roads Queensland
- Main Roads Western Australia
- Department for Transport, Energy and Infrastructure South Australia
- Department of Infrastructure, Energy and Resources Tasmania
- Department of Planning and Infrastructure Northern Territory
- Department of Territory and Municipal Services Australian Capital Territory
- Department of Infrastructure, Transport, Regional Development and Local Government
- Australian Local Government Association
- New Zealand Transport Agency.

The success of Austroads is derived from the collaboration of member organisations and others in the road industry. It aims to be the Australasian leader in providing high quality information, advice and fostering research in the road sector.

SUMMARY

Heavy vehicle safety is a continuing concern in both Australia and New Zealand. On behalf of Austroads, ARRB Group undertook to identify the road related factors that contribute to heavy vehicle crashes on Australian and New Zealand freight routes. Four key tasks were carried out.

1. An analysis of crash data collected in Australia and New Zealand revealed that the characteristics of heavy vehicle crashes matched those for ‘all crashes’ in terms of at least some of the variables investigated. However, heavy vehicle crashes did differ in some respects from crashes that do not involve a heavy vehicle. For example, ‘same direction’ crashes account for a higher proportion of heavy vehicle crashes.
2. Inspections of heavy vehicle crash cluster sites along selected freight routes were used to identify the road and road environment factors which may have contributed to the occurrence or severity of heavy vehicle crashes. The factors identified included poor delineation, narrow lanes, limited sight distance and clear zone hazards.
3. A workshop enabled ARRB to gather stakeholders’ opinions on the factors identified during the site inspections, on additional issues that should be considered in improving the safety of the road environment for heavy vehicles, and on appropriate countermeasures.
4. Published and unpublished literature was consulted to provide guidance on road design techniques and countermeasures that could be applied to address the road and road environment factors identified during the site inspections and workshop. Road geometry, traffic control devices, intersection design and pavement surface are included among the topics covered.

A draft strategy for addressing heavy vehicle safety on major freight routes and recommendations for revisions to the Austroads Road Safety Audit Checklists and were developed based on the findings which emerged from these tasks.

The Road Safety Audit Checklists already flag heavy vehicle traffic as requiring consideration in relation to numerous facets of road design including off-street loading and unloading facilities and overtaking opportunities. Some additional issues noted relate to:

- height clearances to structures
- horizontal alignment
- signage at rest areas
- signage on grades
- signage at intersections
- signage reflectivity
- storage capacity of lanes
- acceleration and deceleration lanes
- intersection signage
- edge of seal drop-off
- clear zones
- local area traffic management (LATM) treatments
- railway level crossings
- clearance times for signalised intersections.

Activities which could comprise part of a strategy for addressing heavy vehicle safety on major freight routes in the short term and the longer term are presented. The importance of some solutions listed within the National Heavy Vehicle Strategy 2003-2010, such as clearance of roadside hazards, shoulder sealing, passing lanes, and programs to minimise the risk posed by utility poles were supported. Further investigation of some of the other promising solutions listed in the strategy, such as the use of barriers to reduce the risk posed by roadside hazards, audible edge lining for heavy vehicles and delineation appears warranted. Other appropriate long term measures pertain to skid resistance treatments, lane widths and the continuation of the safe system approach for heavy vehicles.

The following actions could be undertaken within the more immediate future:

- Amendments and additions that more strongly focus on heavy vehicles should be incorporated into the revised Austroads Road Safety Audit guide (2002b).
- A simplified risk assessment guideline for roadside hazard assessment, cost estimation and prioritisation, which includes reference to heavy vehicles, should be incorporated within the Road Safety Audit Checklists.
- The Road Safety Audit training course should be expanded to reflect the greater emphasis on heavy vehicle safety in the revised Road Safety Audit guide.
- The appropriateness of sight distances associated with existing overtaking zones on major heavy vehicle freight routes should be assessed.
- Road design guidelines should be reviewed in terms of:
  - suitability of various service road access point designs for heavy vehicles
  - suitability of minimum required lane widths for heavy vehicles at speeds greater than 90 km/h.
- Work identifying the site characteristics (including minimum heavy vehicle volumes) which make various heavy vehicle specific road design features cost effective should be built on, to aid in proactive risk minimisation.
- ITS solutions to heavy vehicle crash problems (e.g. intelligent rollover warning signs, advisory speed signs on curves) should be reviewed.
- The role of road surface characteristics (e.g. texture and rutting) on heavy vehicle crash risk should be researched.
- Skid resistance criteria for heavy vehicle safety should be researched.
- The effectiveness of rest areas in promoting heavy vehicle safety should be investigated.

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1 INTRODUCTION

1.1 Background

Heavy vehicle safety is a continuing concern in both Australia and New Zealand. The National Heavy Vehicle Safety Strategy 2003 – 2010 (NTC 2002a) highlights the following evidence in establishing heavy vehicle safety as a significant issue:

- The NTC Truck Benchmarking Study (Haworth, Vulcan & Sweatman 2002) shows that Australia trails international best performance in terms of fatalities resulting from crashes involving a truck per km of truck travel.
- Crashes involving heavy vehicles are estimated to cost Australia around $2 billion a year and to kill around 330 people, while injuring many more.
- Despite improvements in the early to mid 1990s, when fatalities resulting from heavy vehicle crashes fell substantially, the numbers of fatalities have remained relatively static since 1996.
- Since the mid 1990s, the freight task has increased substantially, as have the registrations of articulated vehicles.
- The total freight task is expected to almost double in the next 20 years, suggesting that heavy vehicle crash prevention will pose even greater challenges if national road safety targets are to be met.

A number of studies have drawn attention to the role of road design and infrastructure in heavy vehicle crashes (e.g. Haworth & Symmons 2003; Haworth et al. 2002).

Developing a safe systems approach for heavy vehicles could have a major impact in improved heavy vehicle safety and hence reduce their contribution to road trauma.

1.2 Purpose and Outputs

The purpose of this project was to evaluate the interaction between heavy vehicles and the road system to identify issues related to heavy vehicle crashes, and develop specific proposals to improve the system performance on heavy freight routes. This report:

- presents an overview of heavy vehicle crash characteristics
- identifies freight routes with safety problems
- provides a draft strategy to improve the safety of these heavy vehicle freight routes
- suggests revisions to the Austroads Road Safety Audit guide to take better account of heavy vehicle safety issues.

2 METHOD

2.1 Consultation

Consultations with jurisdictions were held to determine the adequacy of existing analyses of heavy vehicle crash sites. A representative of each state road authority in Australia, and the Ministry of Transport in New Zealand, was contacted by phone or e-mail and asked to provide information on existing analyses of heavy vehicle crashes.

2.2 Analysis of Crash Data

Heavy vehicle crash data (which, for the purposes of comparison was analysed alongside crash data for ‘all’ vehicles) contained in Australian and New Zealand road authority crash databases was disaggregated by:

- type of heavy vehicle involved (i.e. rigid truck, articulated vehicle and buses)
- type of crash
- time of day
- road surface (sealed/unsealed)
- road surface condition (i.e. wet/dry)
- weather condition (i.e. clear, raining, foggy, etc.)
- light conditions (i.e. day, night, dusk or dawn)
- horizontal and vertical road alignment
- (at intersections) type of control (i.e. Stop, Give Way, signalised, unsignalised, etc.)
- location (urban/rural, based on definitions provided within the respective state crash database)
- speed zone.

Table 2.1 describes that road authority crash data that was available for analysis.

Table 2.1: Data available for analysis

Jurisdiction	Years
New South Wales	01 Jan 1999 – 31 Dec 2003
Victoria	01 Jan 1999 – 31 Dec 2003
Queensland	01 Jan 1999 – 31 Dec 2003
Western Australia	01 Jan 1999 – 31 Dec 2003
South Australia	01 Jan 1998 – 31 Dec 2002
Tasmania	01 Jan 1999 – 31 Dec 2003
Northern Territory	01 Jan 1999 – 31 Dec 2003
New Zealand	01 Jan 1999 – 31 Dec 2003

No ACT data was available at the time analyses were conducted[1]. Only casualty crashes (any injury level) were of interest for the present purpose. A heavy vehicle crash was deemed to be any crash where at least one heavy vehicle was involved. A crash between two heavy vehicles was considered to represent one heavy vehicle crash. Property damage only crashes were not included because not all jurisdictions record such crashes.

It should be noted that even where results are presented for each jurisdiction separately, the information contained in this report is not designed to provide for a comparison between jurisdictions. This is because exposure to crash risk (due to factors such as the amount of heavy vehicle traffic) and crash data recording practices, including criteria for a ‘casualty’ crash, vary considerably between jurisdictions.

It should also be noted that some crash characteristics that were of interest are not recorded in all jurisdictions. Where this was the case (or when, despite being recorded, information was not contained within the data held by ARRB) the jurisdictions for which the relevant information was not available are noted in the text associated with the relevant tables or figures.

A second limitation is the fact that the categories employed by jurisdictions to describe crash characteristics vary. For example, in Western Australian crash data, vertical alignment can be recorded as level, crest or slope. However, in other jurisdictions vertical alignment can be recorded as level, crest, slope or dip. In some cases, categories have been collapsed to create categories that correspond with those employed in other jurisdictions.

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[1] The ATSB publication *Road Deaths Australia 2004 Statistical Summary* (2005) indicates that between 1999 and 2003 in the ACT there were five fatal crashes involving an articulated truck and two fatal crashes involving a bus. The presence of ACT data in the analyses conducted would therefore have been unlikely to alter the overall picture of heavy vehicle crash characteristics on a national level.

Analyses of Australian data were presented separately for buses, rigid trucks and articulated trucks. This is the greatest level of detail permitted by the vehicle type categories recorded in Australian crash data as a whole. Although some jurisdictions allow for finer distinctions between truck types, the usefulness of these categories is limited by the accuracy with which vehicle type is recorded. New Zealand crash records do not distinguish between articulated and rigid trucks. Table 2.2 describes the definitions of bus, rigid truck and articulated truck that are employed for each jurisdiction.

Table 2.2: Definitions of a heavy vehicle

Jurisdiction	Bus	Rigid	Articulated
NSW	STA bus coach other bus	large rigid rigid tanker	road train B-double articulated tanker semi-trailer
VIC	bus/coach	truck (not semi trailer)	semi trailer
Qld	omnibus	truck tow truck	articulated road train
WA	bus	truck prime mover	truck & 1 trailer prime mover & 1 trailer road train
SA	omnibus	truck	semi trailer
Tas	bus school bus	rigid truck	semi trailer log truck B-double
NT	coach (tourist) other bus passenger bus	rigid truck > 4.5 GVM rigid truck < 4.5 GVM	articulated vehicle
NZ	bus	truck	

Analyses of crash data were conducted using SPSS (Statistical Package for the Social Sciences) Version 11.5.

This crash data was also used to select key ‘high heavy vehicle crash frequency’ transport routes between Victoria and Queensland, and some key routes in Western Australia. These states were selected to provide for easy access by ARRB for the crash cluster site inspections that would take place on the ‘high crash frequency routes’ (Section 2.3) and thus maximise the number of sites that could be inspected within the resources available for the project.

For Western Australia, routes with a high frequency of heavy vehicle crashes were initially selected based on the number of crashes that occurred on each between 1999 and 2003. As an alternative means of selection, it would have been possible to derive ‘per kilometre’ crash rates for all major roads in the state. However, this was decided against because per kilometre crash rates for very lengthy routes are often low, even if some segments of the route have very high crash risk. Further, it would be difficult to identify ‘clusters’ of heavy vehicle crashes along any road which has not seen a relatively large number of such crashes.

After crash frequency was used to identify the routes in Western Australia with the highest number of heavy vehicle crashes, the per kilometre crash rate was used to select the two highest risk routes from among the top three.

For Victoria, New South Wales and Queensland, a similar approach was adopted but in this case only roads which were part of a major freight route between the three states were selected. For all states, per kilometre crash rates were calculated for each of the selected roads.

2.3 Site Inspections

Clusters of heavy vehicle crashes along the selected 'high crash frequency' routes were chosen for investigation. The objectives of this component of the project were:

- to identify and inspect sites (along the routes identified) with high numbers of heavy vehicle crashes
- use the results from the inspections to identify design characteristics that influence road safety.

Efforts were made to select clusters to represent each cell of the sampling frame presented in Table 2.3, but it was often difficult to identify crash clusters at rural intersections in particular. It was also difficult to identify 'tight' clusters of heavy vehicle crashes at non-intersections and so some sites, particularly in rural areas were of substantial length but nonetheless represented a cluster of heavy vehicle crashes in relative terms. A list of the sites inspected is presented in Appendix A.

Table 2.3: Number of heavy vehicle crash clusters in each cell of the sampling frame adopted

State	Western Australia		Victoria		New South Wales		Queensland		Total
Location	Intersection	Midblock	Intersection	Midblock	Intersection	Midblock	Intersection	Midblock	
Urban	6	5	7	6	5	6	7	7	49
Rural	0	10	2	7	6	10	1	5	41
Total	6	15	9	13	11	16	8	12	90

The following steps were used to identify intersection crash clusters for inspection:

- Data for 'intersection' heavy vehicle crashes along selected routes was sorted according to intersection identifiers such as intersection name and/or number.
- Crash records for intersections with fewer than three casualty crashes between 1999 and 2003 were removed.
- Urban and rural intersections were selected from the remaining intersections based on the number and severity of crashes and the recency of the crashes that did occur (with priority given to sites with more recent crashes to minimise the likelihood of the site having undergone upgrades since the crashes).
- Some consideration was also given to the location of potential rural investigation sites, with those located long distances from other investigation sites given lower priority in order to ensure that as many sites as possible could be inspected in the time available.

The following steps were used to identify mid-block crash clusters for inspection:

- All heavy vehicle crashes along the selected routes were mapped using the geo-coding variables contained in the state road authority crash databases.
- All rural heavy vehicle crashes that did not occur within two kilometres of another heavy vehicle crash were removed from the map.
- All urban heavy vehicle crashes that did not occur within 200 metres of another heavy vehicle crash were removed from the map.

- Visual inspection of the resulting maps was carried out to identify crash clusters among the remaining crashes.
- Urban and rural midblock sites were selected from the remaining sites based on the overall number and severity of crashes and the per kilometre crash rate of the site.
- Some consideration was also given to the location of rural sites, with those located a long distance from other high risk sites given lower priority in order to ensure that as many sites as possible were inspected in the time available.

Experienced traffic engineers, coached in the conduct of such site inspections, were employed to inspect each high-risk site, aided by the checklist presented in Appendix B. Site inspectors were also provided with a description (including time of day, light conditions, weather conditions and DCA) of the heavy vehicle crashes that occurred at each site based on the respective state road authority crash database. The site inspectors who performed the inspections in Queensland and Victoria were also provided with the brief police narratives associated with the crashes that occurred at the sites they inspected. This additional information was intended to aid in the identification of road factors that may have played a role in the crashes that occurred.

2.4 Literature Review

The topics covered in the literature review reflect the issues identified during the site inspections conducted (and to a lesser extent, the data analysis conducted) that can be addressed through facets of road design. The specific objective of the literature review was to provide comment on the applicability of existing road design guidelines for heavy vehicles in relation to the issues covered, and where these do not provide coverage, offer some guidance as to how selected issues can be addressed.

The databases searched were:

- ATRI – The Australian Transport Index, Australia’s primary database for transport-related material
- TRIS – The National Transportation Library’s Transportation Research Information Service.

This search covered literature from the 1970s up to 2005. The Internet was also searched using the Google search engine. Apart from various Austroads guidelines, a TRB synthesis report entitled *Highway/heavy vehicle interaction* (Harwood Potts Torbic & Glauz 2003) was used extensively.

2.5 Workshop

A full-day workshop was conducted in Melbourne (at the offices of the National Transport Commission) on 24 May 2007 in order to:

1. present an overview of the project and findings to date
2. obtain stakeholder views on road-related heavy vehicle crash causation or severity factors (including any that the project had not yet identified)
3. discuss the implications of the project findings (and any issues raised during the workshop) for the Road Safety Audit Checklists and a draft strategy for heavy vehicle safety on major freight routes.

The workshop was conducted by staff from ARRB Group and the National Transport Commission and attended by representatives of:

- Roads and Traffic Authority New South Wales
- VicRoads
- Queensland Department of Main Roads
- Main Roads Western Australia
- Department for Transport, Energy and Infrastructure South Australia
- Department of Infrastructure, Energy and Resources Tasmania
- Australian Local Government Association.

Much of the information gathered during this workshop has been used to guide the content of this report.

3 PREVIOUS ANALYSES OF HEAVY VEHICLE CRASH SITES

Consultations with state road authority representatives and a representative of the NZ Ministry of Transport revealed that some work has been conducted on a local basis by most jurisdictions. For example, Figure 3.1 depicts a plot of truck crash locations produced by Main Roads WA to help identify heavy vehicle crash black spots. However, such projects tend to be small in size and not typically focussed upon the factors of the roadway that may influence heavy vehicle crashes.

It should also be noted that some relatively general descriptions of fatal crash numbers for articulated trucks and buses are available within the Australian Transport Safety Bureau's annual *Road Deaths Australia: Statistical Summary* (ATSB 2005) which is available for download from the ATSB website. The National Transport Commission's website is also home to the papers presented at the 2002 Heavy Vehicle Safety Seminar (NTC 2002b) which fed into a draft strategy and action plan to be considered as part of the revised National Road Safety Strategy Action Plan. These papers cover topics such as:

- benchmarking
- trends and statistics
- safety initiatives in progress
- issues in driver impairment
- cost-effective improvements and other examples of promising practices from the field
- road and vehicle based safety initiatives.

Figure 3.1: Map used by Main Roads WA to identify heavy vehicle crash blackspots

4 GENERAL CHARACTERISTICS OF HEAVY VEHICLE CRASHES

This chapter presents some of the findings which emerged from the analyses of state road authority data and is broken into three sections covering:

- the number, severity, time and nature of crashes involving at least one heavy vehicle (crash characteristics)
- the light and weather conditions present at the time of crashes involving at least one heavy vehicle, and whether or not the road surface was wet (environmental conditions)
- the features of locations of crashes involving at least one heavy vehicle, including road alignment, traffic control, speed limit and urbanisation (location features).

Additional findings are presented in Appendix C.

4.1 Crash Characteristics

Table 4.1 shows that most of the data presented was collected in New South Wales. There were relatively few crashes involving heavy vehicles recorded in the Northern Territory and Tasmania. In all jurisdictions other than Queensland and New South Wales, there were more injury crashes for rigid trucks than buses and articulated trucks combined. However, for all jurisdictions other than the Northern Territory there were as many or more fatal crashes recorded for articulated trucks than rigid trucks and buses combined.

It should be noted that the data in Table 4.1 represents an underestimate of the number of trucks involved in crashes because some crashes involved more than one truck. Further, for the multi-truck crashes which involved two different classes of truck, the categorisation is misrepresentative for the ‘second’ truck involved.

The proportion of casualty crashes that were fatal was highest for articulated trucks (up to 15%) and typically, lowest for buses (up to 5%) (Table 4.2). Overall, the proportion of heavy vehicle casualty crashes that were fatal was 5.7% for Australia and 9.6% for New Zealand. As noted however, recording practices may account largely for this difference.

Table 4.1: Heavy vehicle casualty crashes (1999 – 2003)

Jurisdiction	Vehicle type	Fatal crashes	Injury crashes
NSW	Bus	58	1,704
	Rigid	154	2,673
	Articulated	292	2,906
	Total	504	7,283
VIC	Bus	17	717
	Rigid	151	3,410
	Articulated	174	2,048
	Total	342	6,175
QLD	Bus	29	1,039
	Rigid	93	2,220
	Articulated	136	1,643
	Total	258	4,902
WA	Bus	17	508
	Rigid	44	1,190
	Articulated	72	588
	Total	133	2,286
SA	Bus	6	331
	Rigid	58	1,132
	Articulated	69	604
	Total	133	2,067
TAS	Bus	4	87
	Rigid	12	315
	Articulated	16	101
	Total	32	503
NT	Bus	3	62
	Rigid	14	149
	Articulated	12	69
	Total	29	280
Australian total	Bus	134	4,448
	Rigid	526	11,089
	Articulated	771	7,959
	Total	1,431	23,496
NZ	Bus	33	574
	Truck	379	3,323
	Total	412	3,897

Table 4.2: Annual average heavy vehicle casualty crashes (1999 – 2003)

Jurisdiction	Casualty crashes	% fatal
NSW	1,557	6.5
VIC	1,303	5.2
QLD	1,032	5.0
WA	484	5.6
SA	440	6.1
TAS	107	5.6
NT	62	9.7
NZ	861	9.5

Figure 4.1 shows that the number of heavy vehicle casualty crashes has remained relatively consistent since 2000 in Australia. Although 2003 saw fewer heavy vehicle crashes than 2002, this could well be random fluctuation. In New Zealand 2002 and 2003 saw a slight increase in heavy vehicle crashes over the previous three years.

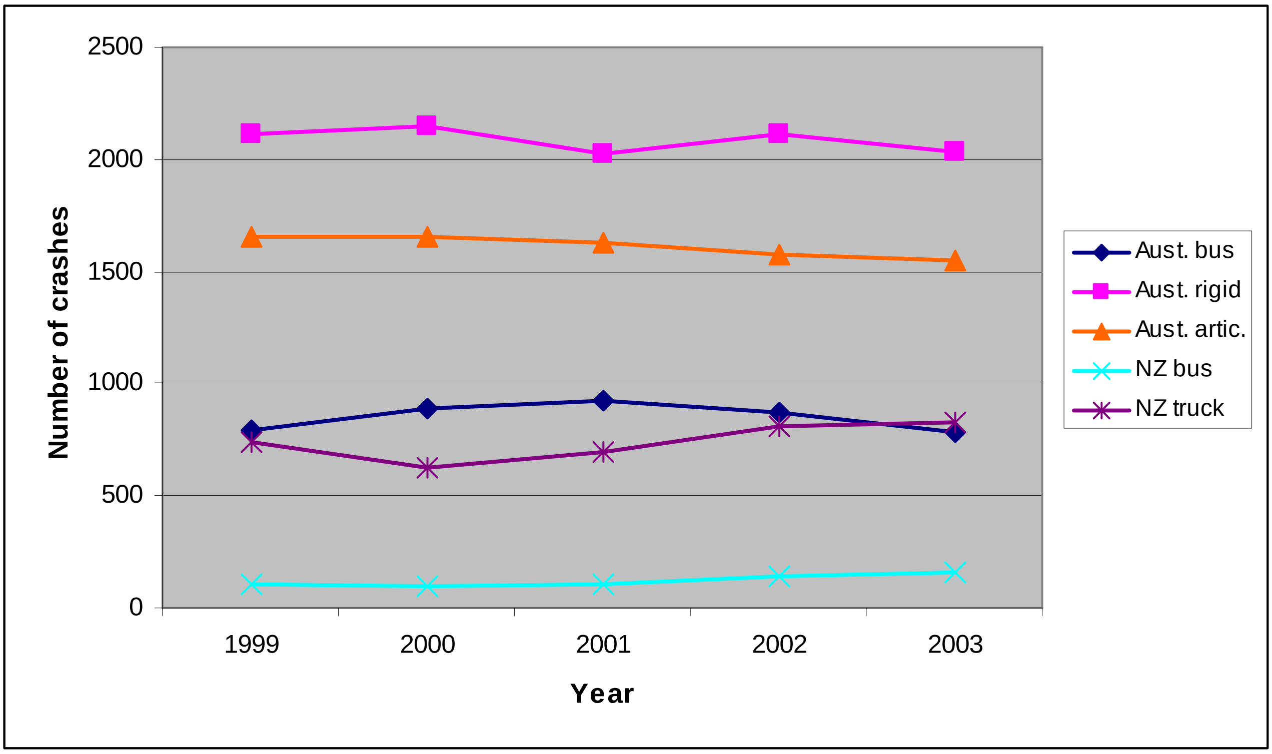

Figure 4.1: Heavy vehicle casualty crashes by year[2]

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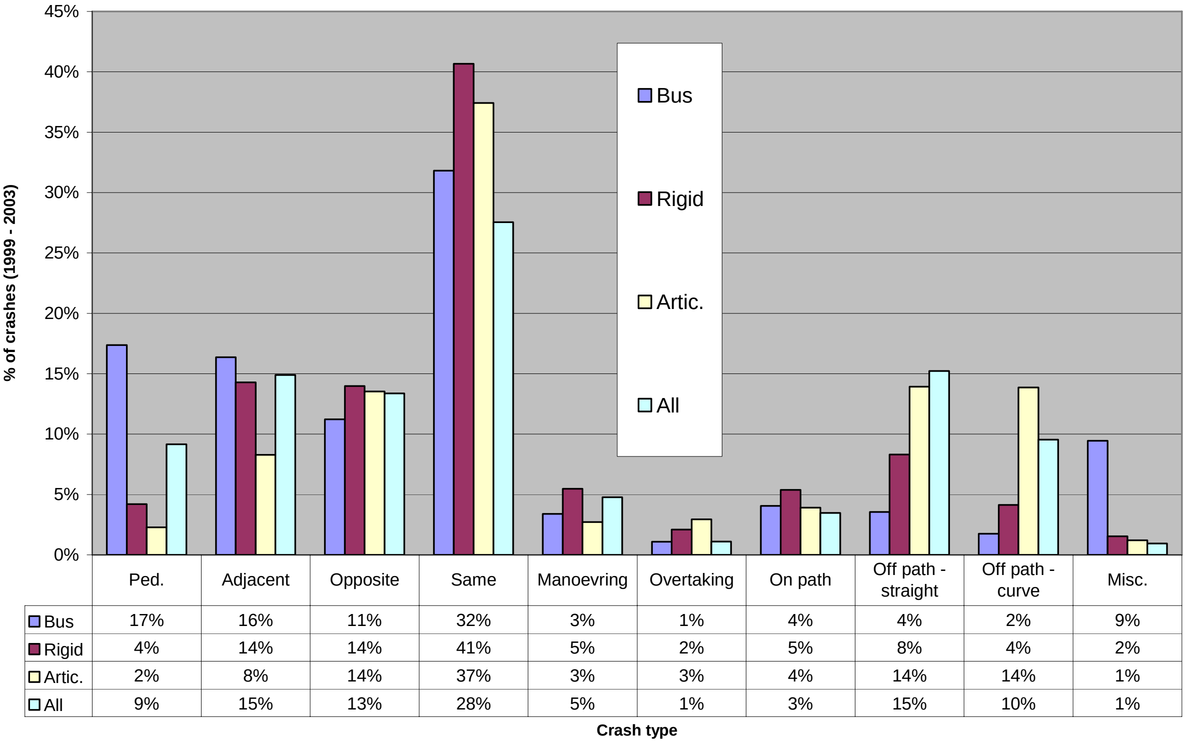
[2] Because South Australian data was not available for 2003, South Australian crashes were not included in this analysis.

Figure 4.2 shows that buses stand out has being involved in a greater number of pedestrian crashes, but are involved in comparatively few run-off road crashes. A smaller proportion of articulated truck crashes are ‘adjacent’ compared to other heavy vehicle crashes and ‘all[3]’ crashes, probably reflecting less exposure in urban environments. Compared to ‘all’ crashes, a higher proportion of heavy vehicle crashes are ‘same direction’ crashes. This probably reflects the lesser braking capabilities of heavier vehicles.

For New Zealand (Figure 4.3) trucks were involved in comparatively few run-off road crashes.



	Ped.	Adjacent	Opposite	Same	Manoevring	Overtaking	On path	Off path - straight	Off path - curve	Misc.
🟪 Bus	17%	16%	11%	32%	3%	1%	4%	4%	2%	9%
🟥 Rigid	4%	14%	14%	41%	5%	2%	5%	8%	4%	2%
🟨 Artic.	2%	8%	14%	37%	3%	3%	4%	14%	14%	1%
🟦 All	9%	15%	13%	28%	5%	1%	3%	15%	10%	1%

Figure 4.2: Crashes by crash type – for comparisons between vehicle types (Australia[4])

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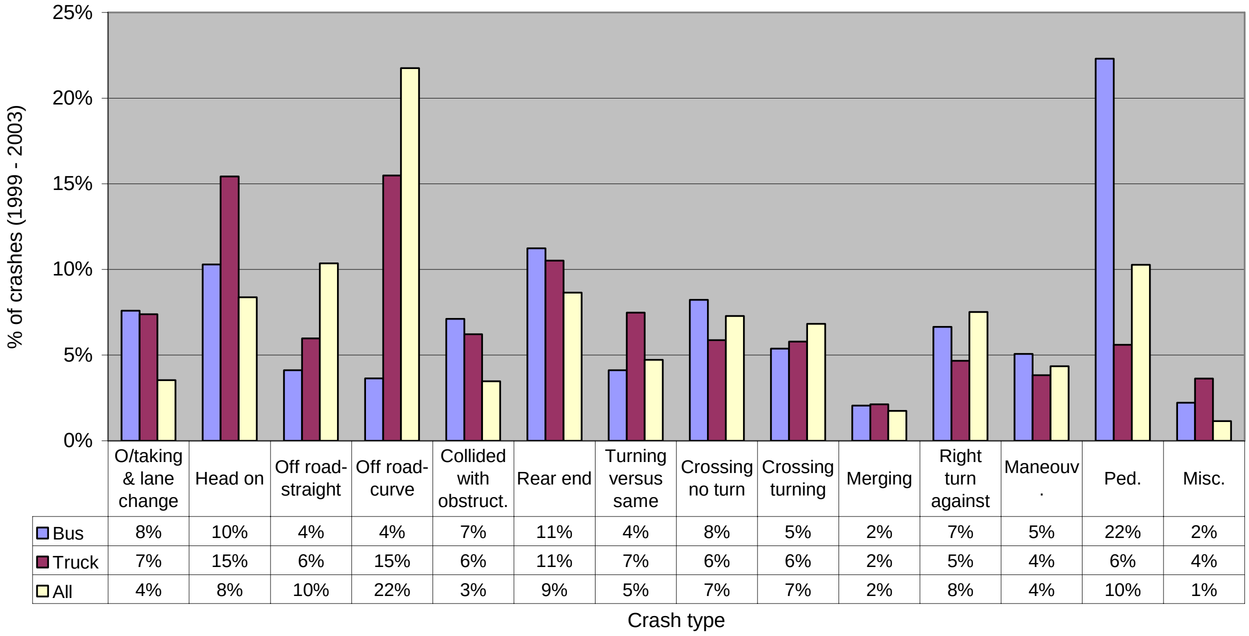
[3] ‘All crashes’ included every casualty crash recorded during the same data period employed for the heavy vehicle crash data. This sample was made up of over 354,000 crashes for Australia and 46,000 crashes for NZ. All crashes were used as a comparison point to show whether or not crash characteristics, in general, are different from heavy vehicle crash characteristics.

[4] Tasmanian and South Australian data is not included as these jurisdiction’s systems for categorising crash types are not reconcilable with those employed by the other jurisdictions.



Crash type	O/taking & lane change	Head on	Off road-straight	Off road-curve	Collided with obstruct.	Rear end	Turning versus same	Crossing no turn	Crossing turning	Merging	Right turn against	Maneouv.	Ped.	Misc.
🟦 Bus	8%	10%	4%	4%	7%	11%	4%	8%	5%	2%	7%	5%	22%	2%
🟥 Truck	7%	15%	6%	15%	6%	11%	7%	6%	6%	2%	5%	4%	6%	4%
🟨 All	4%	8%	10%	22%	3%	9%	5%	7%	7%	2%	8%	4%	10%	1%

Figure 4.3: Crashes by crash type - for comparisons between vehicle types (New Zealand)

Analysis of crash type by urbanisation (presented in Appendix C) revealed that in Australia, the majority of urban crashes involving all three types of heavy vehicle involve a collision with a vehicle that was travelling in the same direction. This includes rear-end and lane change crashes. In rural areas, off-path crashes are more predominant than same direction collisions for articulated trucks.

For buses, other major crash types in both urban and rural environments include adjacent and head-on. Out of control (or off-path) crashes were also predominant in rural road environments while pedestrian crashes accounted for 10% of urban bus crashes.

In New Zealand off-path and head-on collisions predominate among rural bus and truck crashes. In urban New Zealand environments pedestrian crashes represent almost one quarter of bus crashes, while no one DCA group predominates among truck crashes.

4.2 Environmental Conditions

Most crashes occurred during daylight in both Australia and New Zealand (Figure 4.4 and Figure 4.5). Compared to buses and rigid trucks, articulated trucks in Australia appear to be somewhat overrepresented in crashes which occur in darkness. This is probably due to their travel patterns, which involve a considerable amount of night-time travel.

For both Australia and New Zealand, heavy vehicle crashes appear no more likely to occur on a wet road than all crashes (Appendix C for more detail).

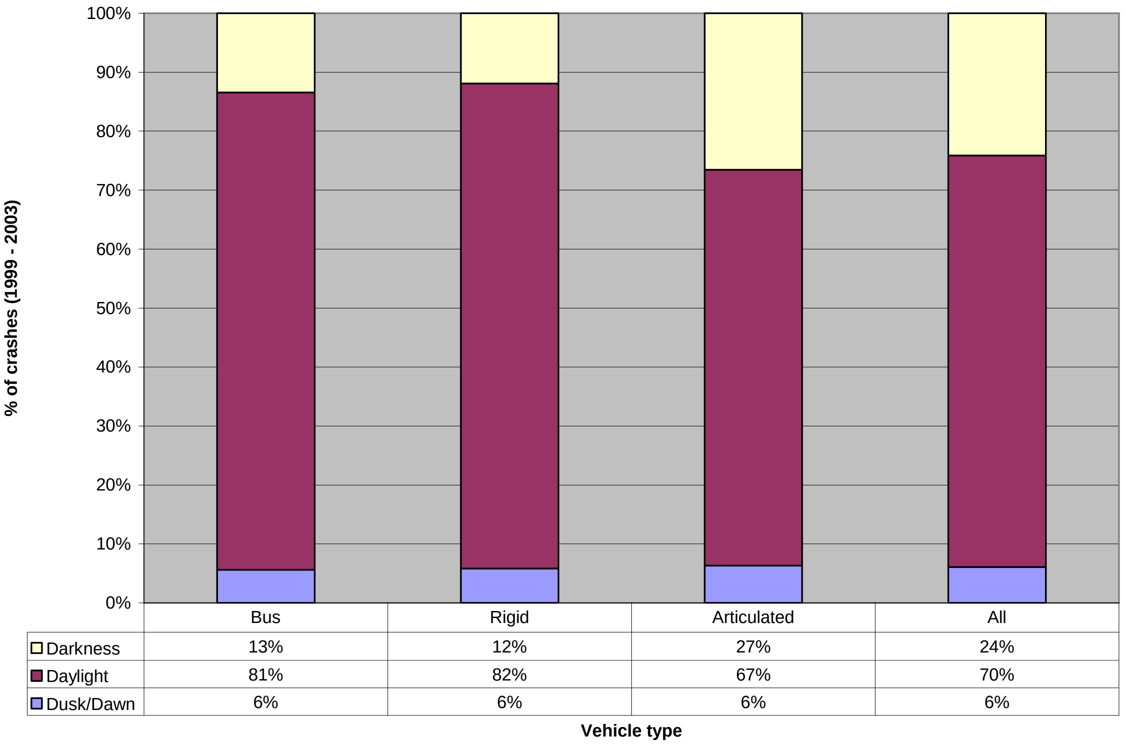


Figure 4.4: Crashes by light conditions (Australia)

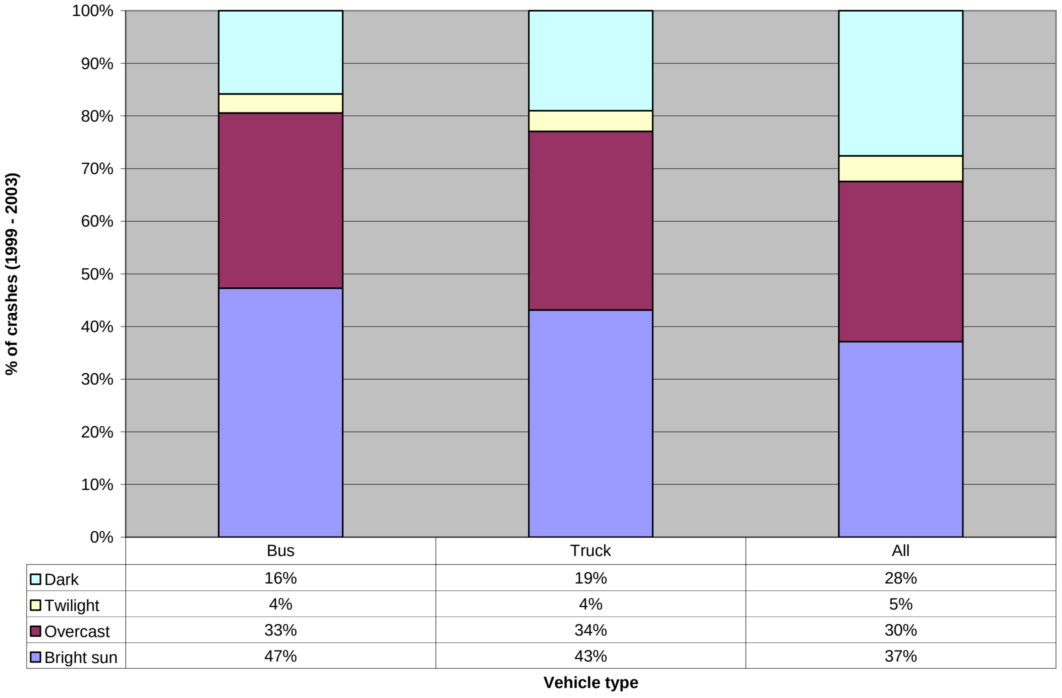
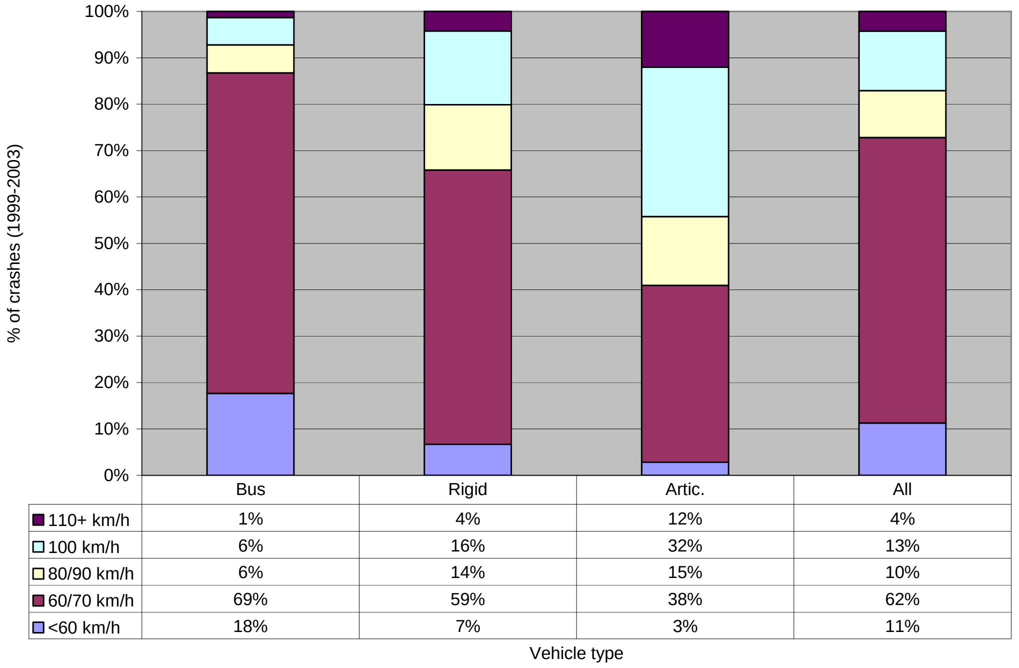


Figure 4.5: Crashes by light conditions (New Zealand)

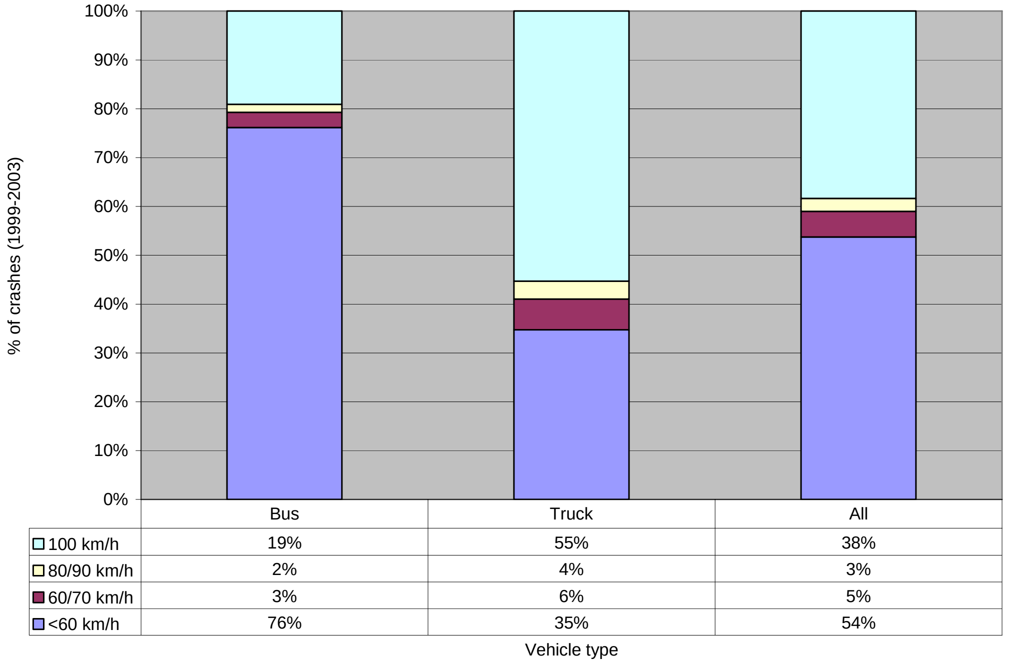
4.3 Location Features

In Australia, buses and rigid trucks are most likely to crash in 60 or 70 km/h speed zones. Articulated trucks are also most likely to crash in 60 or 70 km/h zones but almost as likely to crash in a 100 km/h zone (Figure 4.6). Rigid truck crashes appear to exhibit similar characteristics to 'all crashes'. For New Zealand over half the truck crashes occur in 100 km/h speed zones (Figure 4.7), this is a high proportion, compared even to articulated truck crashes in Australia.



	Bus	Rigid	Artic.	All
■ 110+ km/h	1%	4%	12%	4%
□ 100 km/h	6%	16%	32%	13%
□ 80/90 km/h	6%	14%	15%	10%
■ 60/70 km/h	69%	59%	38%	62%
■ <60 km/h	18%	7%	3%	11%

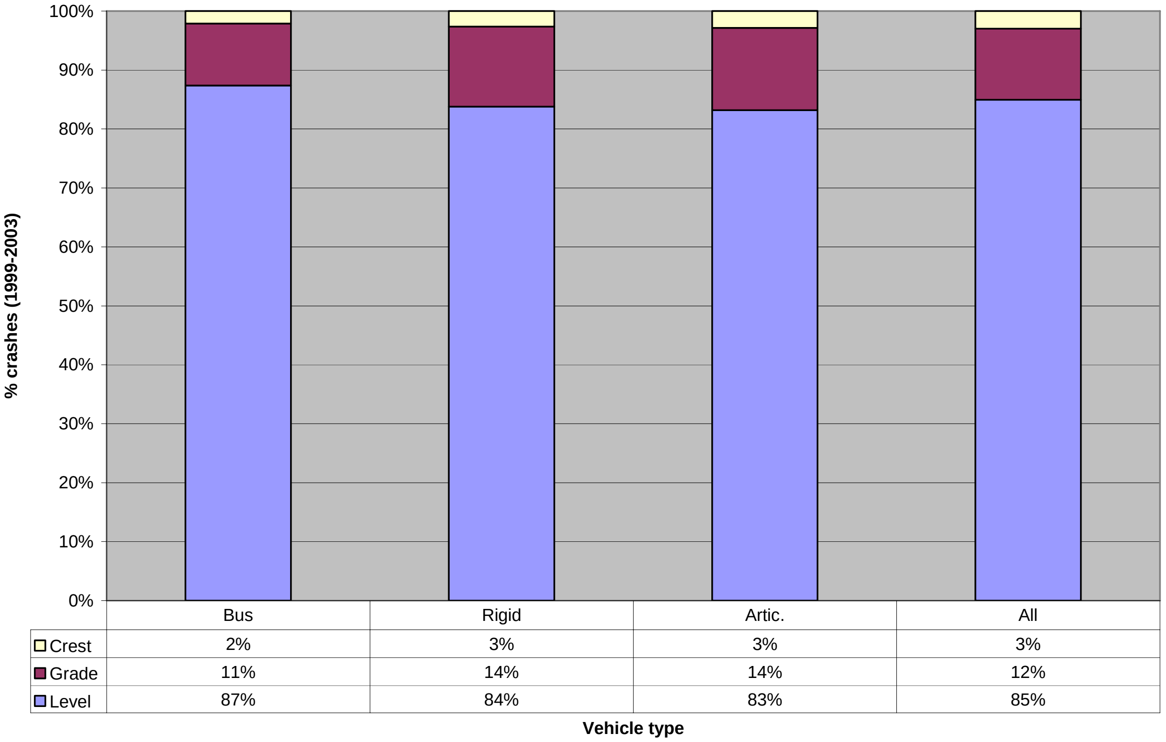
Figure 4.6: Crashes by posted speed limit (Australia)



	Bus	Truck	All
□ 100 km/h	19%	55%	38%
□ 80/90 km/h	2%	4%	3%
■ 60/70 km/h	3%	6%	5%
■ <60 km/h	76%	35%	54%

Figure 4.7: Crashes by posted speed limit (New Zealand)

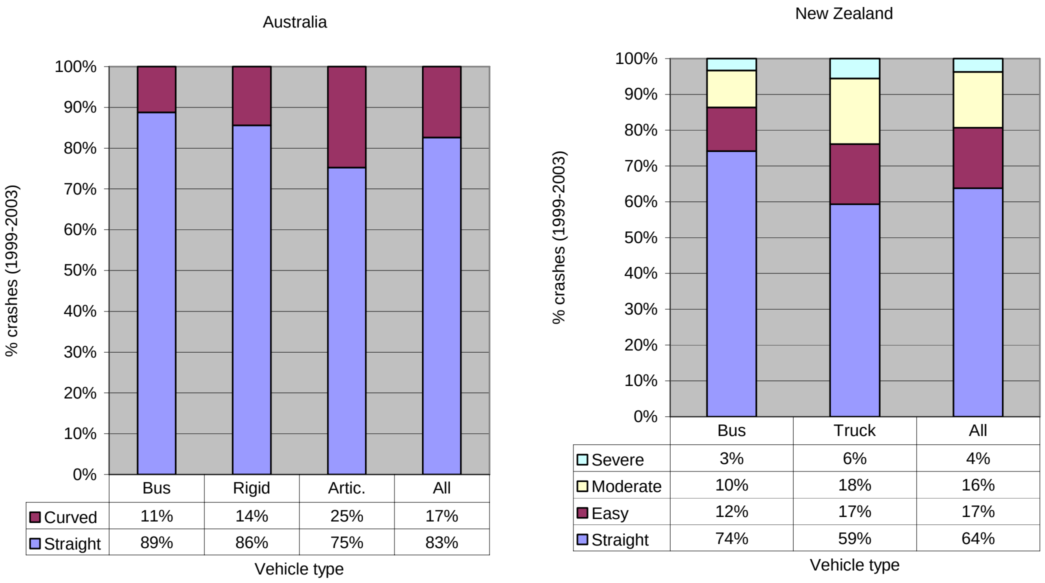
Figure 4.8 shows that in Australia, most heavy vehicle crashes occur on level sections of road.



	Bus	Rigid	Artic.	All
□ Crest	2%	3%	3%	3%
■ Grade	11%	14%	14%	12%
■ Level	87%	84%	83%	85%

Figure 4.8: Crashes by vertical alignment (Australia[5])

Figure 4.9 shows that for both New Zealand and Australia most crashes that involved a heavy vehicle occurred on a straight section of road. For Australia, articulated trucks appear to be over-represented on crashes that occurred on bends.



	Bus	Rigid	Artic.	All
■ Curved	11%	14%	25%	17%
■ Straight	89%	86%	75%	83%

	Bus	Truck	All
□ Severe	3%	6%	4%
□ Moderate	10%	18%	16%
■ Easy	12%	17%	17%
■ Straight	74%	59%	64%

Figure 4.9: Crashes by horizontal alignment

Figure 4.10 shows that more crashes involving rigid and articulated trucks occur at midblocks than occur at intersections. This is not the case for bus crashes.

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[5] ARRB does not hold vertical alignment data for Victorian crashes.

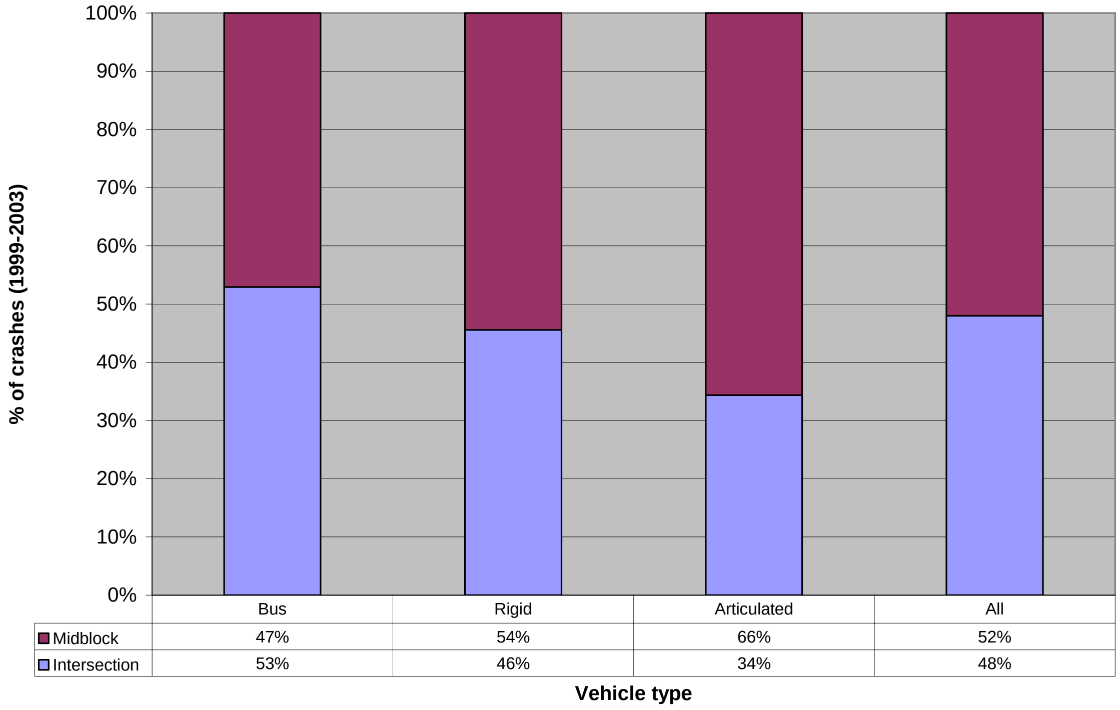

Figure 4.10: Crashes by location (Australia)

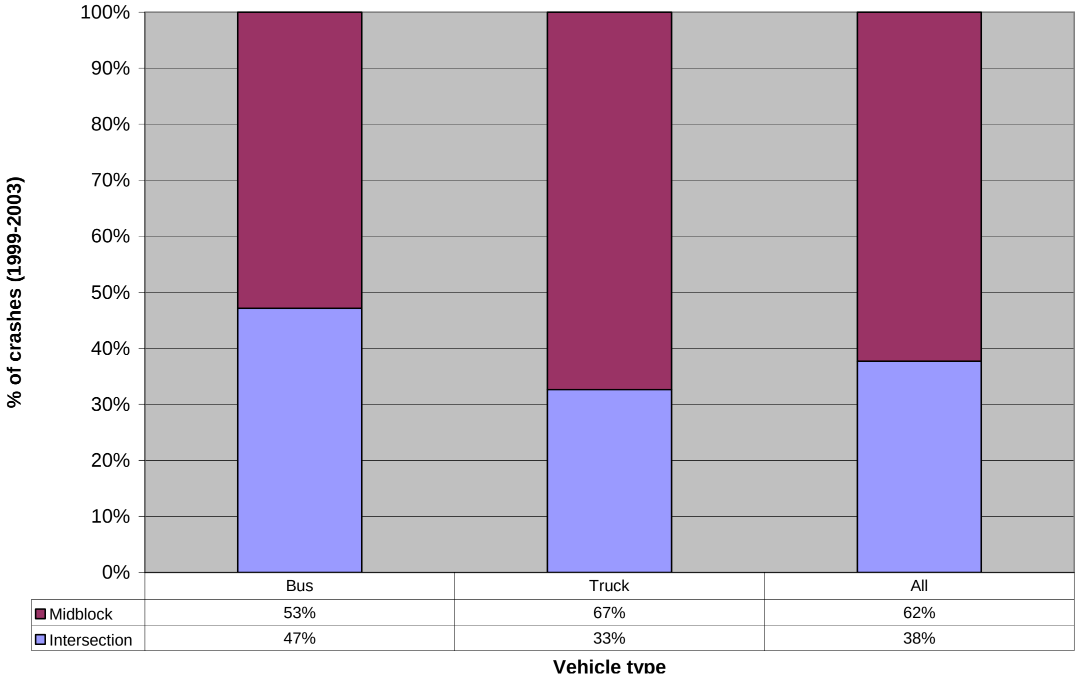

Figure 4.11: Crashes by location (New Zealand)

Of the intersection crashes recorded in Australia, most occurred where there were no traffic controls or at traffic signals. This was true for all categories of vehicle. In New Zealand, most intersection crashes, for all vehicle categories, occurred where there were no traffic control or at a give way sign (details are presented in Appendix C).

In both Australia and New Zealand, most bus crashes occurred in urban areas (Figure 4.12). This was also the case for rigid truck crashes in Australia. Articulated truck crashes in Australia were equally likely to occur in urban and rural locations. In New Zealand, trucks were more likely to have crashed on 'open roads'.

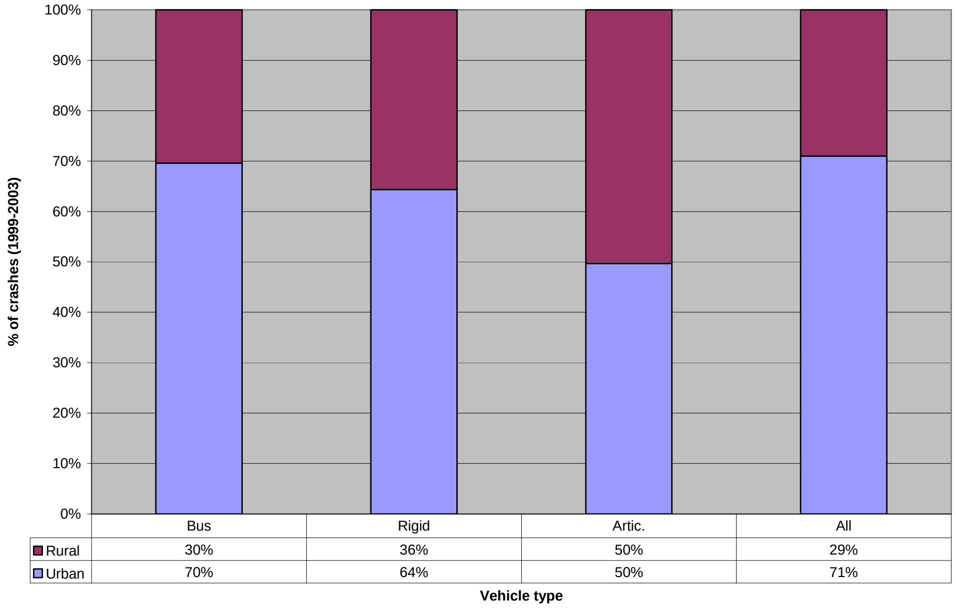

Figure 4.12: Crashes by urbanisation (Australia)

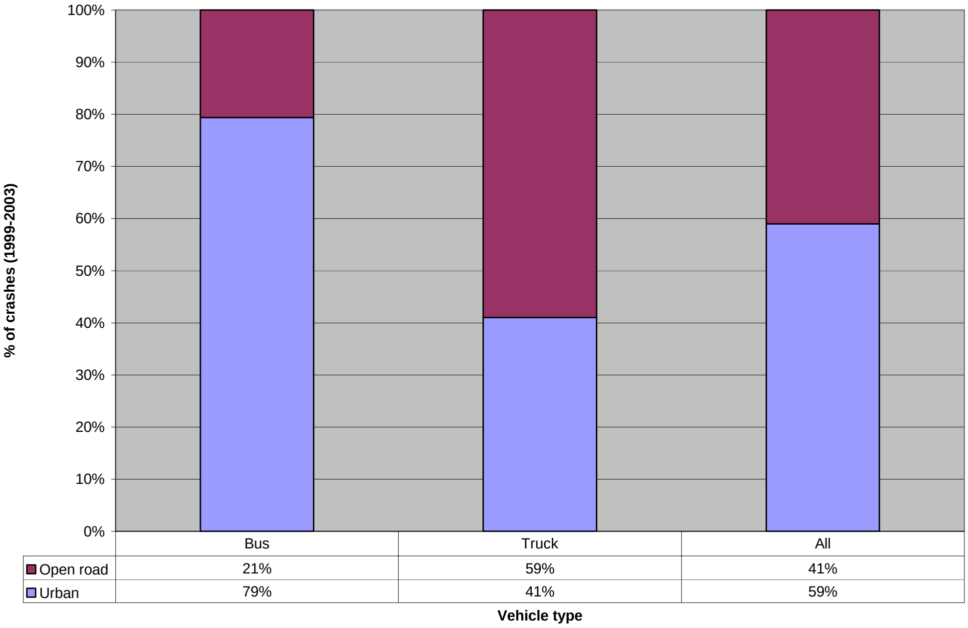

Figure 4.13: Crashes by urbanisation (New Zealand)

4.4 Summary of Heavy Vehicle Crash Characteristics

There are several limitations inherent in aggregating crash data collected by different jurisdictions that should be borne in mind when interpreting the results of the analysis conducted. Nonetheless, according to this analyses:

- There were more casualty crashes for rigid trucks than articulated trucks or buses but crashes involving an articulated truck were more likely to be fatal.

- The number of heavy vehicle crashes in Australia was relatively consistent during the study period but there was a slight increase in New Zealand in 2002 and 2003.
- About one in five bus or rigid truck crashes occurs in darkness or low light, a smaller proportion than for ‘all crashes’.
- Articulated trucks are over-represented (compared to other vehicle types) among darkness and low light casualty crashes and also among crashes that occur on bends.
- About one-quarter of heavy vehicle crashes (and all crashes) in New Zealand occur on a wet road surface and about 15% of heavy vehicle crashes (and all crashes) in Australia occur on a wet road surface.
- Rear-end crashes are the predominant crash type amongst heavy vehicle crashes in Australia but also predominate among ‘all crashes’. In New Zealand, head-on and off-road crashes predominate among truck crashes.
- The large majority of bus crashes occurred in speed zones less than 80 km/h (for Australia and New Zealand). More than 50% of rigid truck crashes (Australia) occur in 60/70 km/h speed zones. About 50% of articulated truck crashes (Australia) and truck crashes (New Zealand) occur in speed zones under 100 km/h.
- Bus and rigid truck crashes are predominantly urban crashes while articulated truck and truck (NZ) crashes are predominantly rural/open road crashes.
- Although the crash patterns for each heavy vehicle category matched those for ‘all crashes’ in terms of at least some of the variables investigated, the crash characteristics for none of the heavy vehicle categories investigated in this project matches that of ‘all crashes’ consistently across the variables measured. This suggests that heavy vehicle crashes, as a whole, differ in some respects from crashes that do not involve a heavy vehicle.

It is important to note that the above conclusions are based on descriptive analyses only. No inferential analyses were performed and so it is not possible to drawn conclusions about the ‘statistical significance’ or lack thereof, of the trends identified.

5 HIGH CRASH FREQUENCY ROUTES

Crash data was used to select two freight routes in Western Australia and freight routes linking Victoria, New South Wales and Queensland for further investigation via crash cluster site inspections. The method of route selection is described fully in Section 2.2.

5.1 Western Australia

Table 5.1 shows the 20 roads within Western Australia that had the highest number of heavy vehicle crashes between 1999 and 2003. These 20 roads accounted for 39% of all recorded heavy vehicle crashes in Western Australia during this period. The Albany, Great Eastern and Leach highways each saw considerably more heavy vehicle crashes than the other 17 roads. The approximate per kilometre heavy vehicle crash rate for each of these roads was as follows:

- Albany Highway – (405 kilometres) – 0.23 heavy vehicle crashes per kilometre for 1999 to 2003.
- Great Eastern Highway – (592 kilometres) – 0.18 heavy vehicle crashes per kilometre for 1999 to 2003.
- Leach Highway – (2 kilometres) – 5.0 heavy vehicle crashes per kilometre for 1999 to 2003.

Based on the frequency of heavy vehicle crashes and per kilometre crash rates, the Albany and Leach highways were selected for further investigation via site inspections. Figure 5.1 and Figure 5.2 show heavy vehicle crash locations for Western Australia and Perth between 1999 and 2003. The Albany and Leach highways are highlighted in blue.

Table 5.1: High crash routes within Western Australia (casualty crashes, 1999 to 2003 inclusive).

Route	Number of HV crashes
KARRINYUP - MORLEY HWY	21
MARMION AVE	22
ARMADALE RD	23
CANNING HWY	24
REID HWY	24
NICHOLSON RD	28
ROE HWY	31
BRAND HWY	33
SOUTH ST	34
WILLIAM ST	37
SOUTH WESTERN HWY	38
MITCHELL FWY	40
KWINANA FWY	42
TONKIN HWY	48
GREAT NORTHERN HWY	63
WANNEROO RD	63
PERTH - BUNBURY HWY	67
ALBANY HWY	95
GREAT EASTERN HWY	106
LEACH HWY	110
Total	949
Total HV crashes in WA	2419

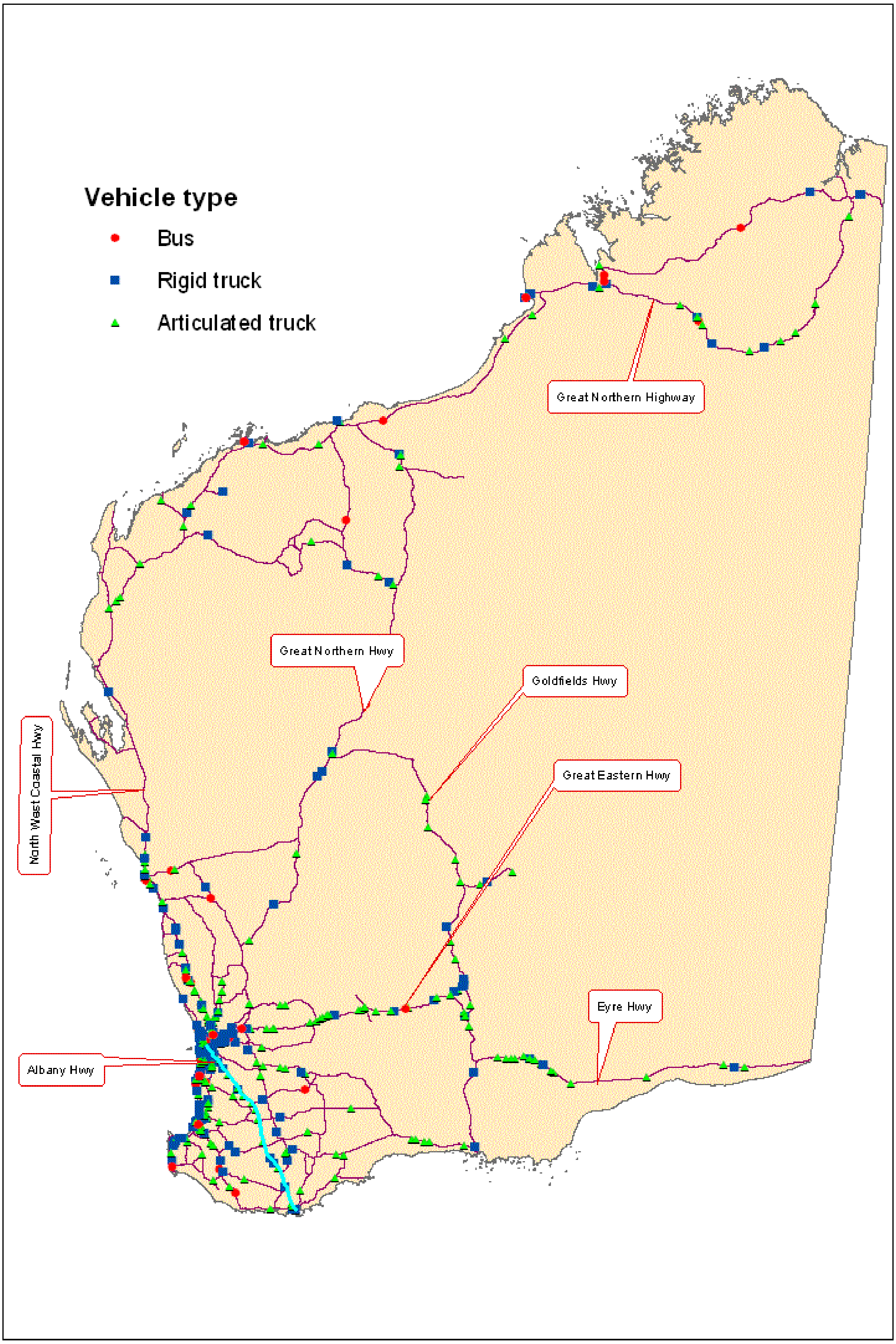

Figure 5.1: Heavy vehicle crashes in Western Australia (casualty crashes, 1999 to 2003 inclusive)

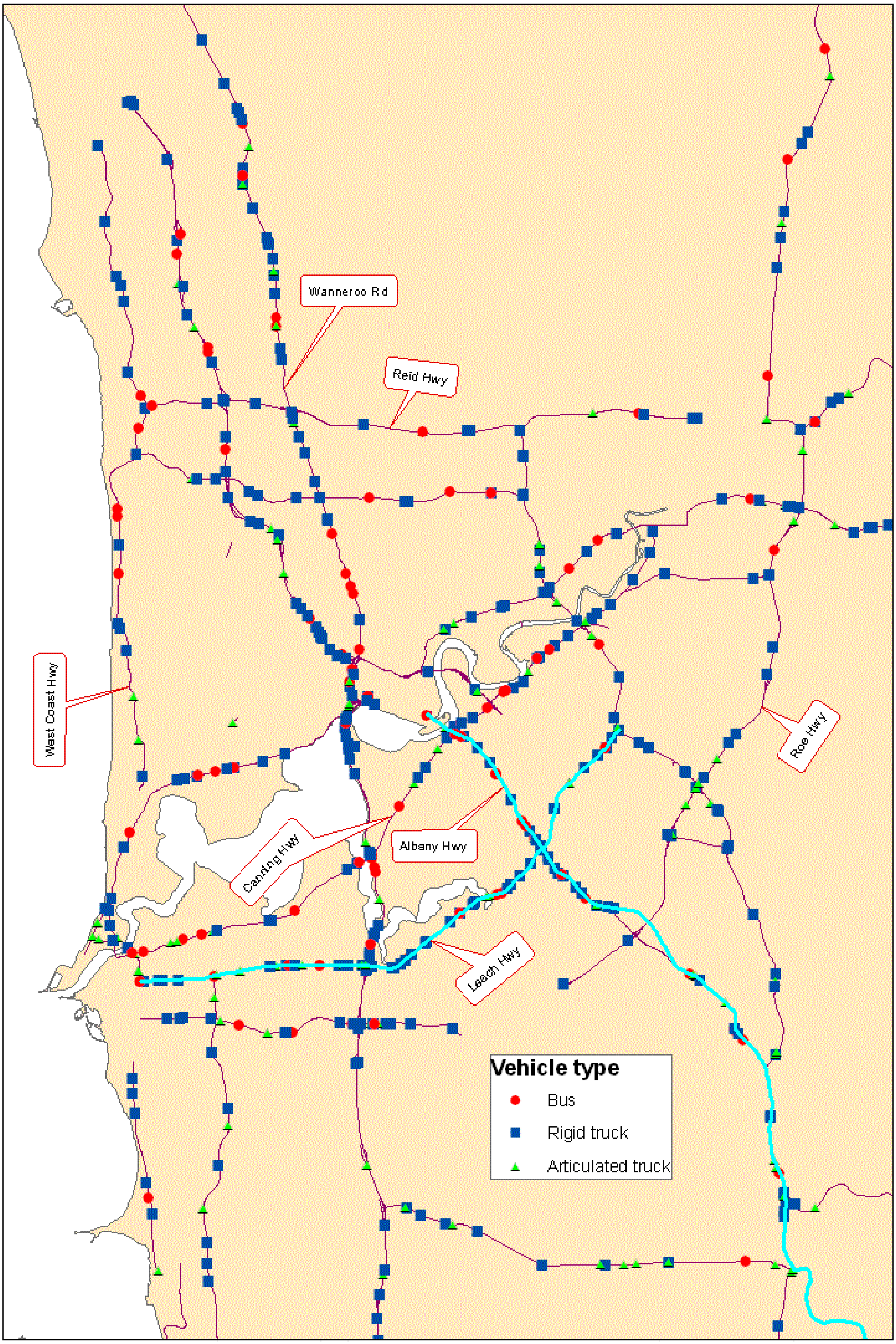

Figure 5.2: Heavy vehicle crashes around Perth (casualty crashes, 1999 to 2003 inclusive)

5.2 Victoria, New South Wales and Queensland

Table 5.2 shows the 20 routes within Victoria that had the highest number of heavy vehicle crashes between 1999 and 2003. These 20 routes accounted for 32% of all recorded heavy vehicle crashes in Victoria during this period. The Hume Highway and Princes Highway (National Route 1) accounted for 10% of all heavy vehicle crashes and, along with the Goulburn Valley Highway, which connects with the Newell Highway in New South Wales, serve as major links between Victoria and New South Wales. The per kilometre crash rate for each of these roads was as follows:

- Goulburn Valley Highway – (257 kilometres) – 0.24 heavy vehicle crashes per kilometre for 1999 to 2003.
- Hume Highway – (297 kilometres in Victoria) – 0.73 heavy vehicle crashes per kilometre for 1999 to 2003.
- Princes Highway (National Route 1) – (954 kilometres in Victoria) – 0.46 heavy vehicle crashes per kilometre for 1999 to 2003.

Although the per kilometre crash rate for the Goulburn Valley Highway was low compared to the other two routes, this highway forms part of a major route between Victoria and New South Wales and ultimately connects with a high heavy vehicle crash frequency route in Queensland (comprised of the Cunningham and Ipswich Highways). Figure 5.3 through to Figure 5.6[6] show heavy vehicle crash locations in Victoria and highlights the Goulburn Valley, Hume and Princes highways.

Table 5.2: High crash routes within Victoria (casualty crashes, 1999 to 2003 inclusive)

Route	Number of HV crashes
FERNTREE GULLY RD	41
BURWOOD HWY	42
CANTERBURY RD	42
WESTERN LINK TOLLWAY	44
DONCASTER-MORDIALLOC RD	45
MURRAY VALLEY HWY	48
CALDER FWY	54
NEPEAN HWY	54
DANDENONG VALLEY HWY	60
GOULBURN VALLEY HWY	61
MIDLAND HWY	72
MAROONDAH HWY	77
SOUTH GIPPSLAND HWY	99
WEST GATE FWY	103
WESTERN RING RD	122
STATE (BELL/SPRINGVALE) HWY	125
MONASH FWY	143
WESTERN HWY	176
HUME HWY	217
PRINCES HWY	442
Total	2067
Total HV crashes	6517

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[6] Crashes on local roads and arterial roads with 10 or fewer crashes are not depicted to preserve image clarity.

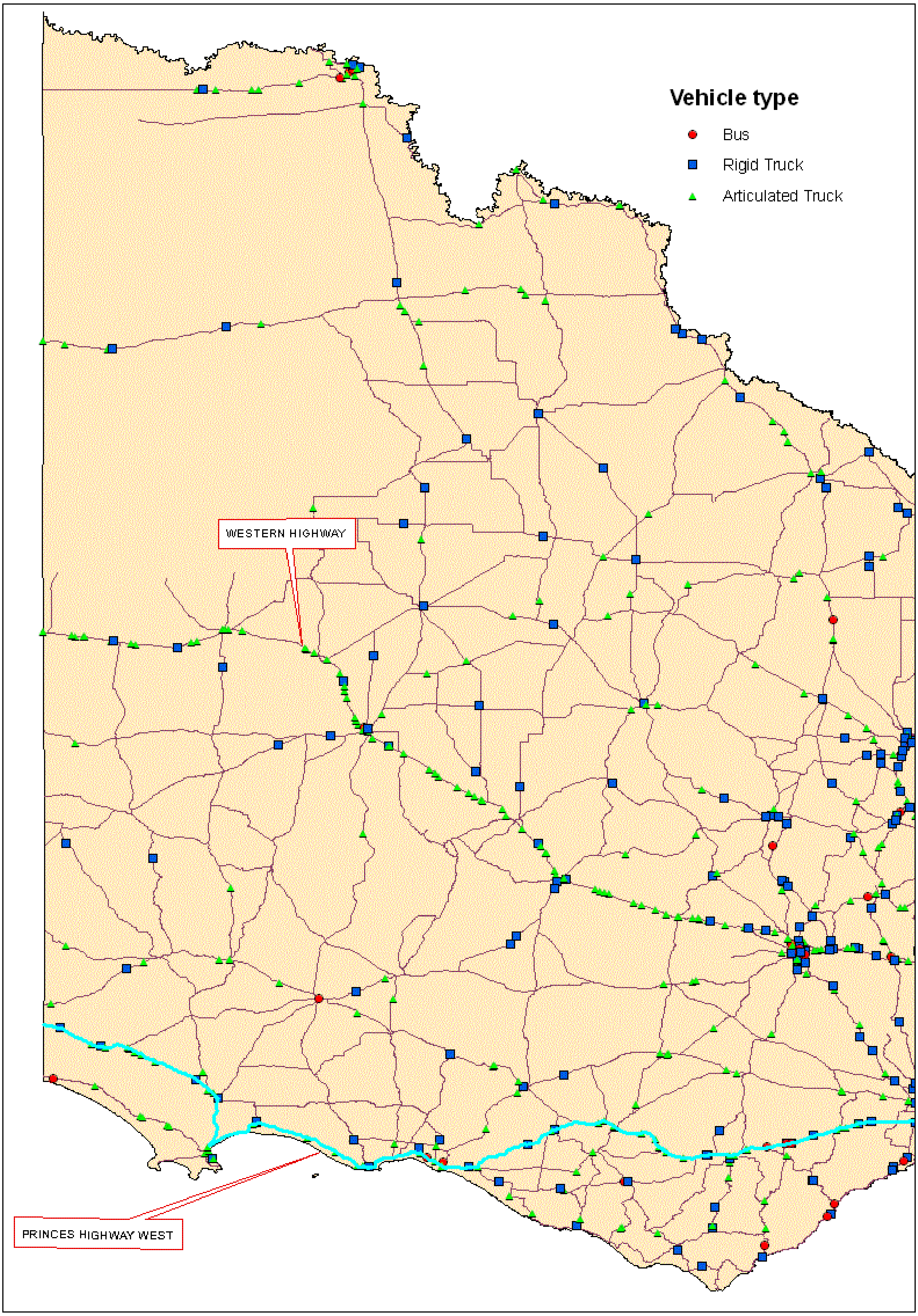

Figure 5.3: Heavy vehicle crashes in western Victoria (casualty crashes, 1999 to 2003 inclusive)

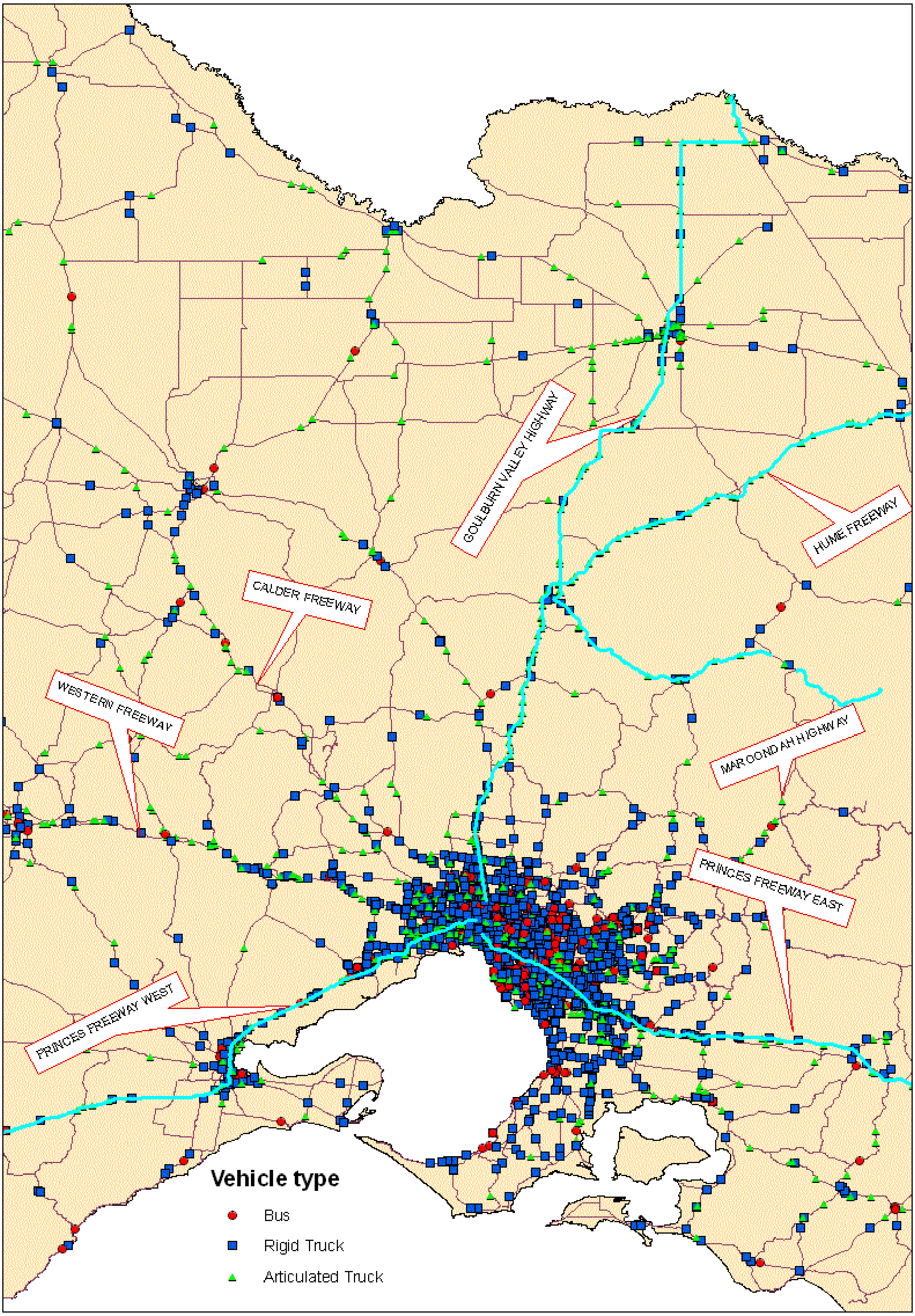

Figure 5.4: Heavy vehicle crashes in central Victoria (casualty crashes, 1999 to 2003 inclusive)

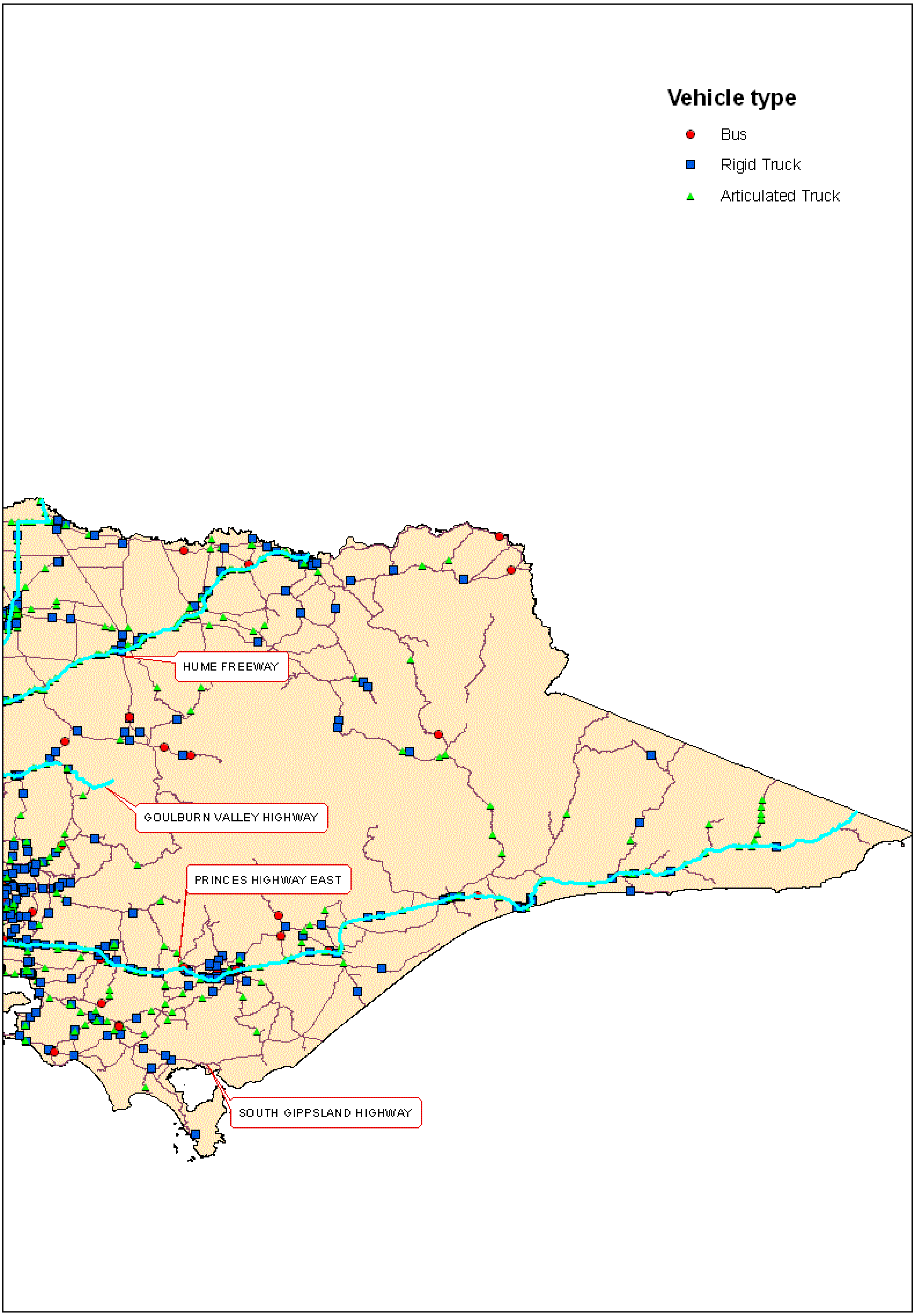

Figure 5.5: Heavy vehicle crashes in east Victoria (casualty crashes, 1999 to 2003 inclusive)

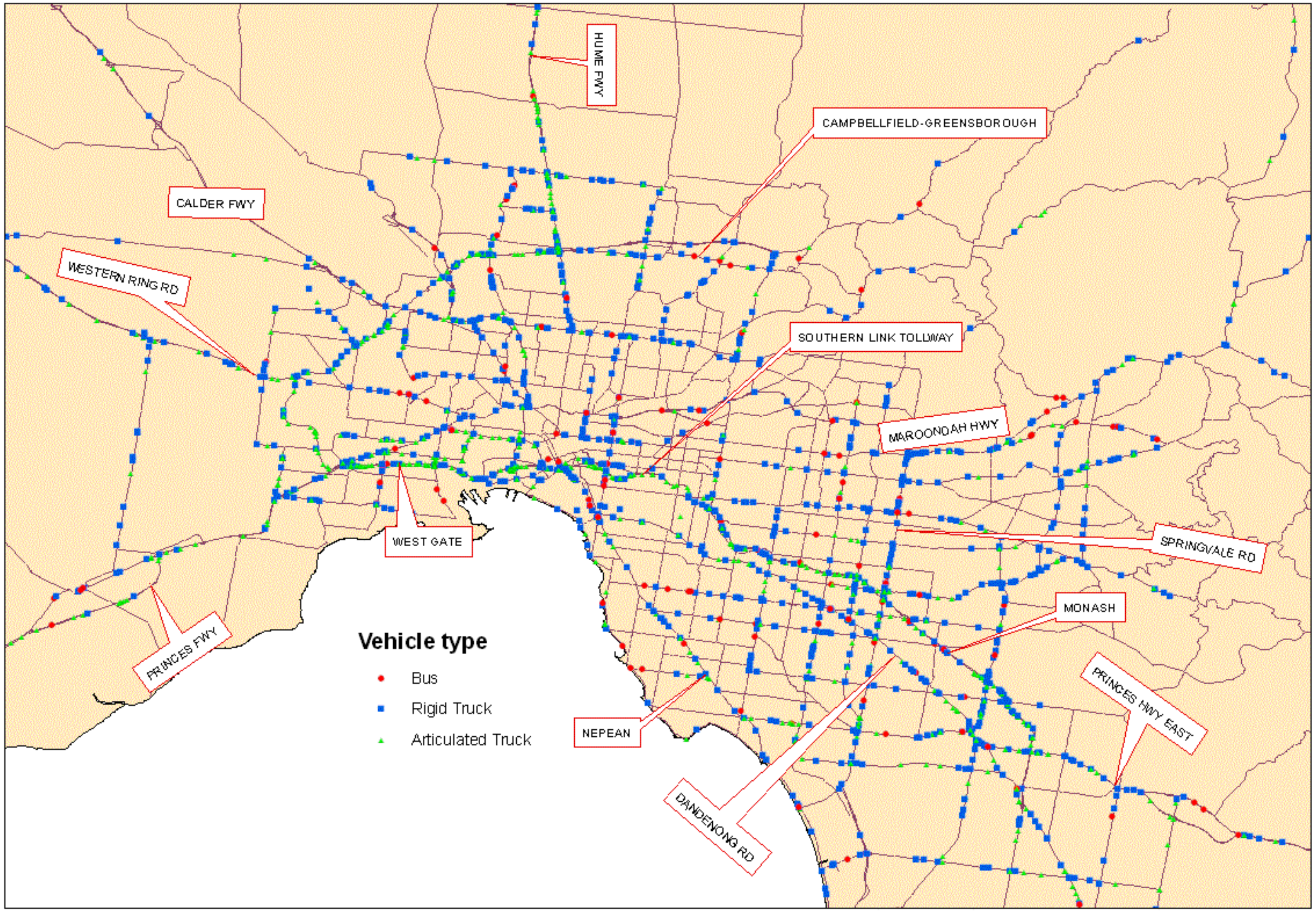

Figure 5.6: Heavy vehicle crashes around Melbourne (casualty crashes, 1999 to 2003 inclusive)

Table 5.3 shows the 20 routes within New South Wales that had the most heavy vehicle crashes between 1999 and 2003. These 20 routes accounted for nearly 40% of all recorded heavy vehicle crashes in New South Wales during this period. The Hume Highway, Cumberland Highway and Princes/Pacific Highway (National Route 1) accounted for just over 18% of all heavy vehicle crashes. Although the Great Western Highway accounted for a considerable percentage of heavy vehicle crashes in New South Wales, this highway does not link to Victoria or Queensland.

The Cumberland Highway is the major link between the Hume and Pacific Highways (although it is currently being replaced by Westlink M7). This relatively short urban road saw a large number of crashes between 1999 and 2003.

Although the frequency of crashes along the Newell Highway was relatively low, the per kilometre crash rate is considerable and this route connects with a high heavy vehicle crash frequency route in Queensland (comprised of the Cunningham and Ipswich Highways) and serves as a major link between Victoria, New South Wales and Queensland.

The per kilometre crash rate for each of the highlighted routes was as follows:

- Cumberland Highway – (35 kilometres) – 6.5 heavy vehicle crashes per kilometre for 1999 to 2003.
- Newell Highway – (1,058 kilometres) – 0.17 heavy vehicle crashes per kilometre for 1999 to 2003.
- Hume Highway – (567 kilometres in New South Wales) – 0.79 heavy vehicle crasher per kilometre for 1999 to 2003.
- Princes Highway and Pacific Highway (National Route 1) – (1,402 kilometres in New South Wales) – 0.53 heavy vehicle crashes per kilometre for 1999 to 2003.

Table 5.3: High crash routes within New South Wales (casualty crashes, 1999 to 2003 inclusive)

Route	Number of HV crashes
CANTERBURY RD	48
WOODVILLE RD	49
SOUTH WESTERN MWY	51
THE HORSLEY DR	51
MITCHELL HWY	56
STURT HWY	62
KING GEORGES RD	62
WINDSOR RD	64
ELIZABETH DR	69
GEORGE ST	80
WESTERN MWY	122
VICTORIA RD	123
SYDNEY - NEWCASTLE FWY	152
NEW ENGLAND HWY	183
NEWELL HWY	184
PRINCES HWY	218
CUMBERLAND HWY	226
GREAT WESTERN HWY	322
HUME HWY	448
PACIFIC HWY	529
Total	3099
Total HV crashes	7787

Figure 5.7 through Figure 5.10 show heavy vehicle crash locations in New South Wales and Sydney and surrounds. The routes identified for further investigation are highlighted.

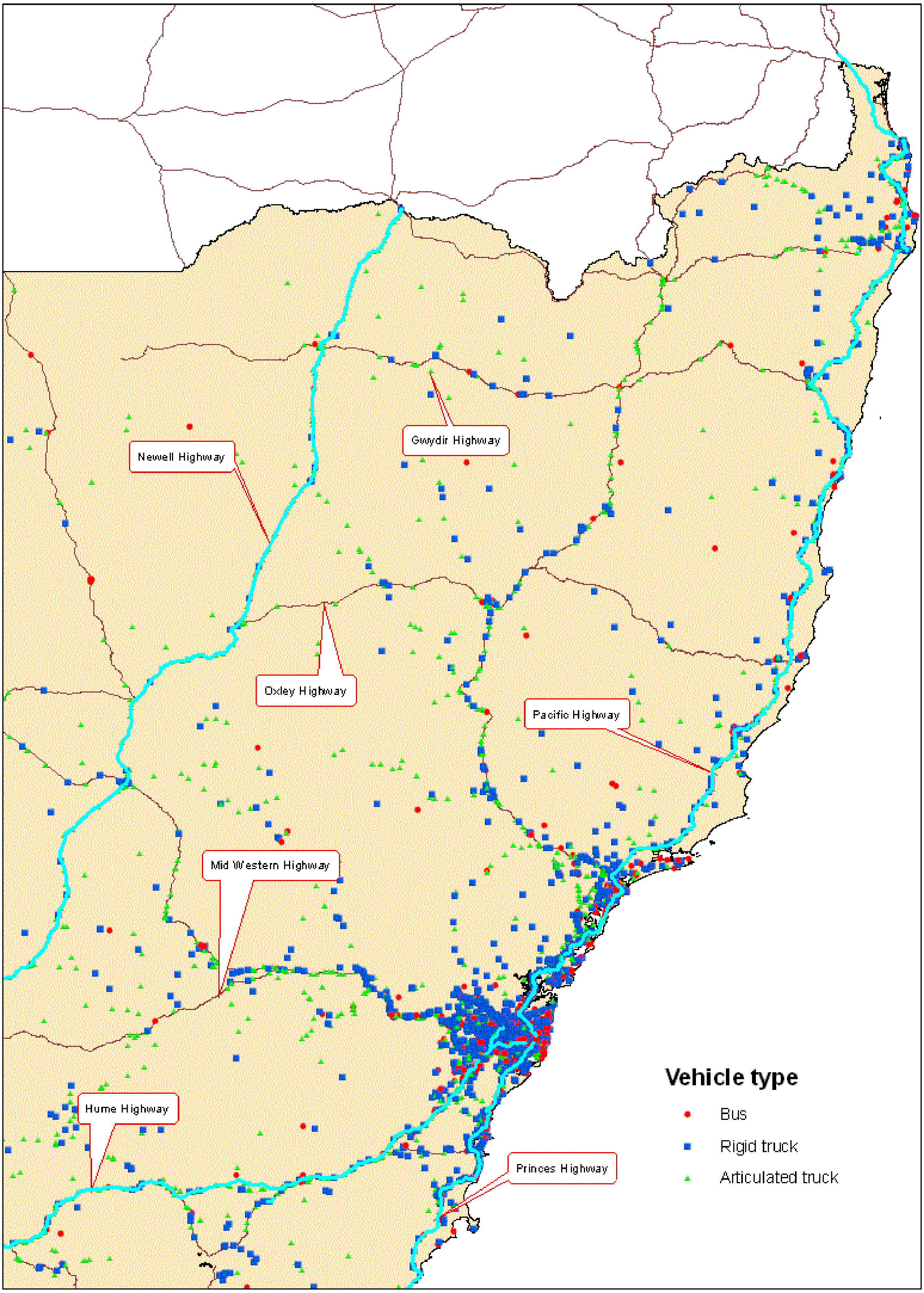

Figure 5.7: Map of heavy vehicle crashes in north eastern New South Wales (casualty crashes, 1999 to 2003 inclusive)

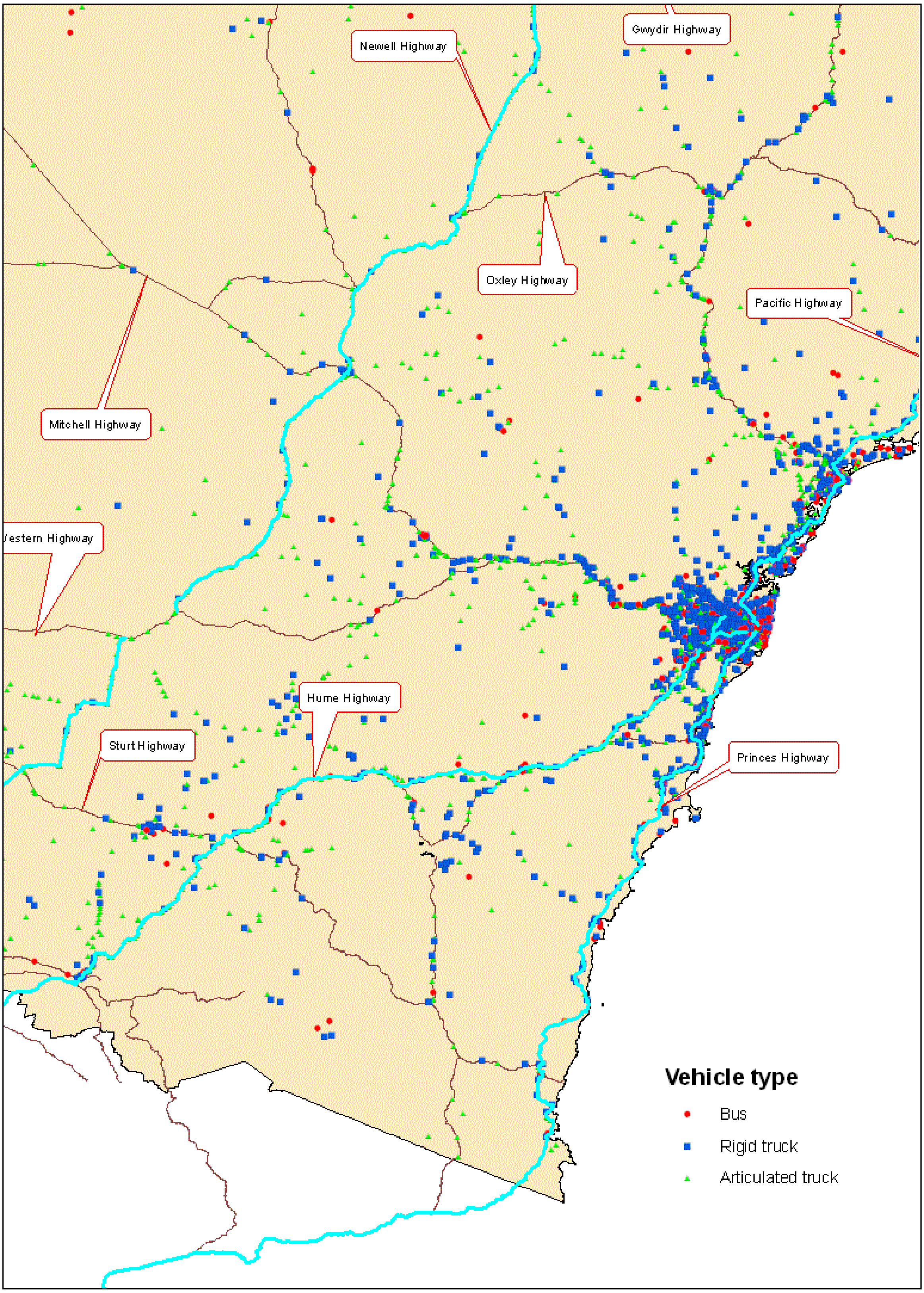

Figure 5.8: Map of heavy vehicle crashes in south eastern New South Wales (casualty crashes, 1999 to 2003 inclusive)

Figure 5.9: Map of heavy vehicle crashes in inland New South Wales (casualty crashes, 1999 to 2003 inclusive)

Figure 5.10: Map of heavy vehicle crashes in Sydney and surrounds (casualty crashes, 1999 to 2003 inclusive)

Table 5.4 shows the 20 routes within Queensland that had the most heavy vehicle crashes between 1999 and 2003. These routes accounted for 32% of heavy vehicle crashes recorded in Queensland during this period.

The roads that make up National Route 1 (Pacific Highway, Gateway Motorway and Bruce Highway) accounted for 14% of all heavy vehicle crashes. While the Warrego Highway also accounted for a considerable percentage of heavy vehicle crashes, this route is not a link between Queensland and New South Wales. The Ipswich Motorway and Cunningham Highway (which link to each other) also accounted for a large number of heavy vehicle crashes. The Cunningham Highway links with the Newell Highway, which traverses New South Wales and then joins the Goulburn Valley Highway in Victoria. The Newell and Goulburn Valley Highways feature in New South Wales' and Victoria's list of 20 high risk routes for heavy vehicle crashes respectively. The per kilometre crash rate for each of these roads was as follows:

- Pacific Highway, Gateway Motorway and Bruce Highway (National Route 1) – (1,832 kilometres in Queensland) – 0.39 heavy vehicle crashes per kilometre for 1999 to 2003.
- Ipswich Motorway – (19 kilometres) – 5.2 heavy vehicle crashes per kilometre for 1999 to 2003.
- Cunningham Highway – (328 kilometres) – 0.32 heavy vehicle crashes per kilometre for 1999 to 2003.

Table 5.4: High crash routes within Queensland (casualty crashes, 1999 to 2003 inclusive)

Route name	Number of HV crashes
FLINDERS HWY	27
MT LINDESAY HWY	28
CAPRICORN HWY	30
BRISBANE - BEENLEIGH RD	33
ADELAIDE ST	35
NEW ENGLAND HWY	36
ANN ST	37
D'AGUILAR HWY	41
GYMPIE RD	41
GORE HWY	47
GRIFFITH ARTERIAL RD	51
SOUTH EAST ARTERIAL RD	53
IPSWICH RD	61
GOLD COAST HWY	90
IPSWICH MWY	99
PACIFIC MWY	99
CUNNINGHAM HWY	105
GATEWAY MWY	115
WARREGO HWY	135
BRUCE HWY	511
Total	1674
Total HV crashes	5160

Figure 5.11 through Figure 5.13 show heavy vehicle crash locations in Queensland. The routes identified for further investigation are highlighted.

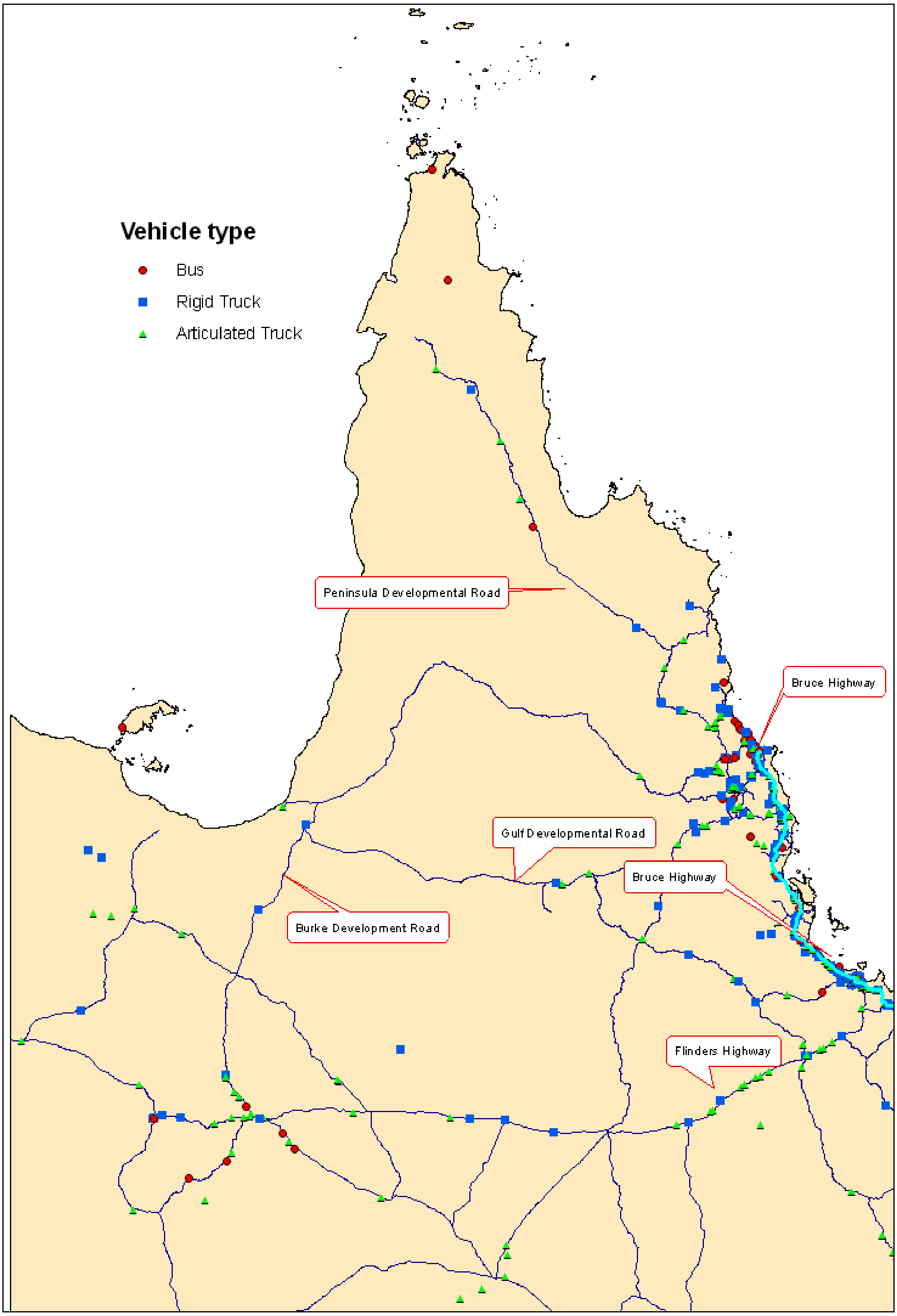

Figure 5.11: Map of heavy vehicle crashes in northern Queensland (casualty crashes, 1999 to 2003 inclusive)

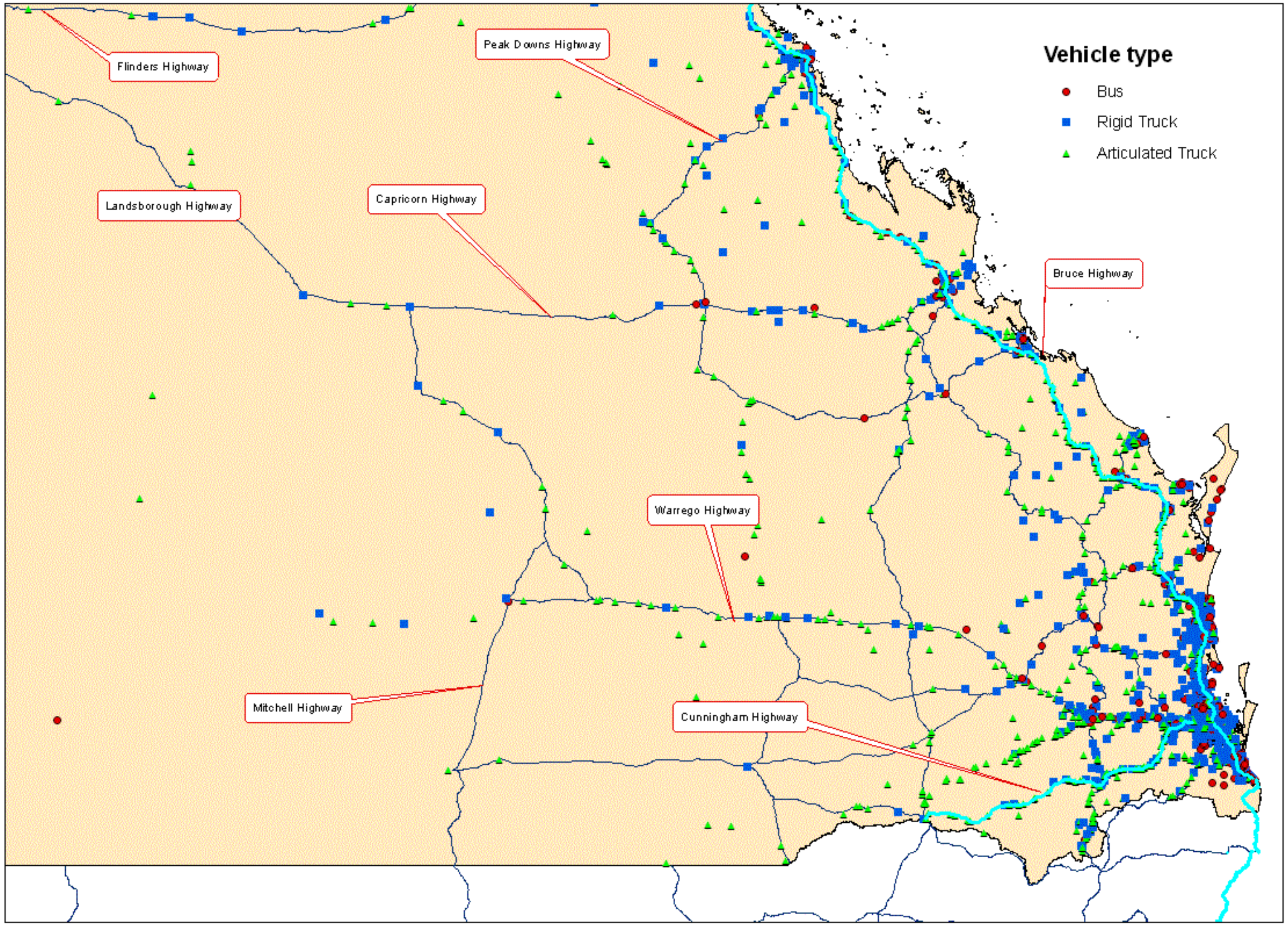

Figure 5.12: Map of heavy vehicle crashes in southern Queensland (casualty crashes, 1999 to 2003 inclusive)

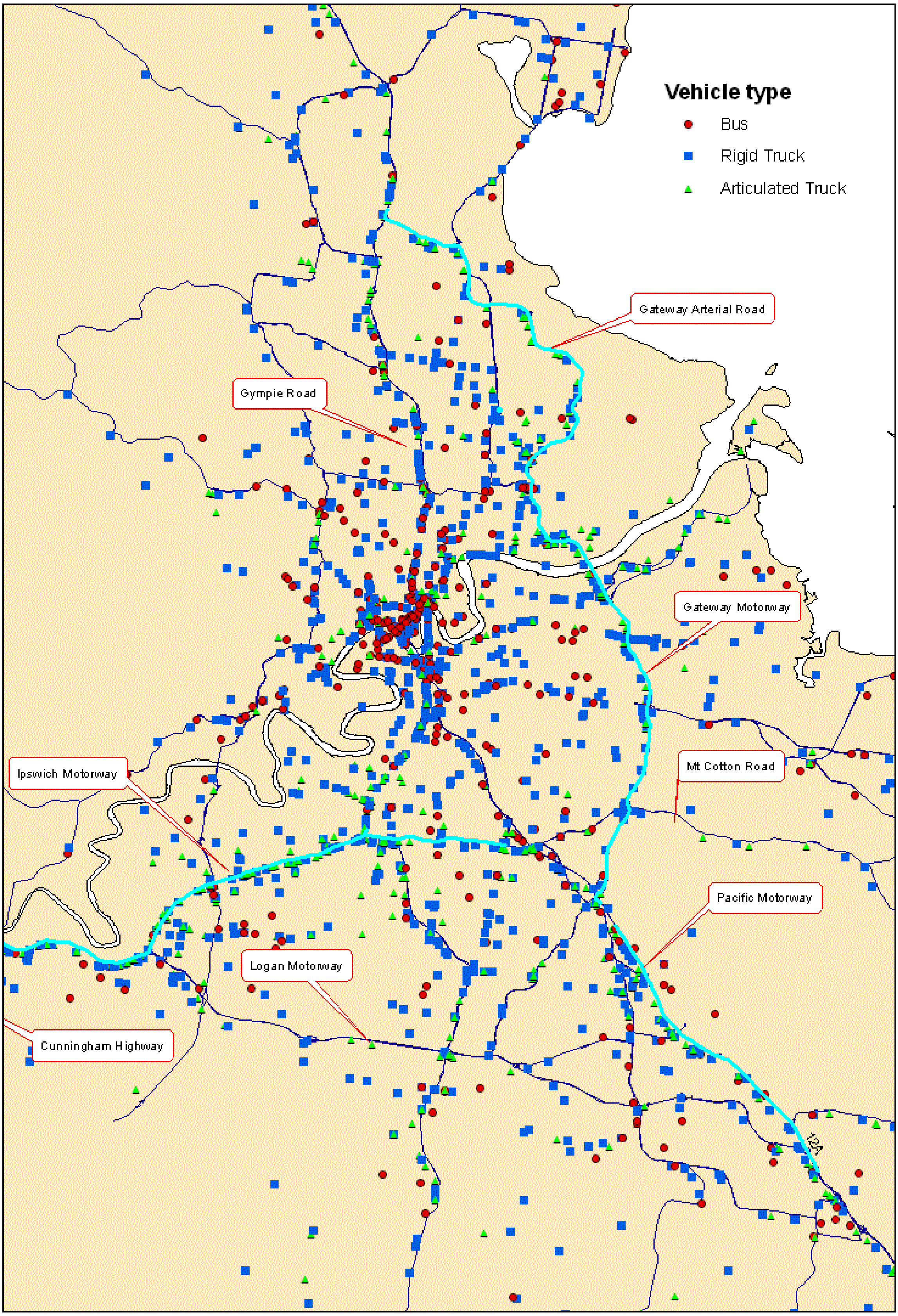

Figure 5.13: Map of heavy vehicle crashes in Brisbane and surrounds (casualty crashes, 1999 to 2003 inclusive)

5.3 Routes for Further Investigation

Based on the information presented, crash clusters were selected (using geo-coding variables contained in the state road authority crash data) from those located on the following routes:

- Albany Highway (Western Australia)
- Cumberland Highway (New South Wales)
- Cunningham Highway (Queensland)
- Goulburn Valley Highway (Victoria)
- Hume Highway (Victoria, New South Wales)
- Ipswich Motorway (Queensland)
- Leach Highway (Western Australia)
- National Route 1 (Victoria, New South Wales, Queensland)
- Newell Highway (New South Wales).

6 SITE CHARACTERISTICS

Findings from the site inspections are presented in this section of the report. First, aggregate results are presented to provide an overall impression of the road environment factors that may have contributed to the heavy vehicle crashes that occurred at the sites inspected.

Following this, brief case studies are presented to provide examples of how state road authority crash data, and information gathered during the site inspections were combined to arrive at hypotheses about crash causation and severity factors. In so doing, these examples also highlight how some road environment factors might (in combination with driver factors, vehicle factors, traffic factors and other road environment factors) contribute to heavy vehicle crashes at particular locations.

It must also be noted that at many sites, no road related factors became apparent to inspectors, while at other sites, only one or two potentially dangerous characteristics were noted. As such even the most frequently apparent factors were typically present at less than one in four sites within the category (e.g. midblocks). Figures depicting the results summarised below are presented in Appendix D.

The major (presented in bold text) and less predominant potential crash contributory factors identified for midblocks were:

- **poor sight distance for overtaking (rural only)**
- **retro-reflective pavement markers not provided (largely rural)**
- **unclear vehicle path through the road segment**
- **road pavement too narrow (largely urban)**
- **road pavement poorly maintained (largely urban)**
- unsatisfactory re-entry to the carriageway from service roads
- poor sight distance at ‘other’ access points such as private driveways
- glare due to the sun (largely urban)
- insufficient signing, including advisory and warning (urban only)
- signs hidden or inconspicuous (urban only).

The potential crash severity factors identified for midblocks were:

- **trees within clear zone (largely rural)**
- **‘other’ roadside hazards within clear zone (largely rural)**
- **culverts within clear zone (rural only)**
- **partially sealed shoulders (largely rural)**
- **steep embankments**
- **guard fencing not provided (largely rural)**
- guard fencing not fit for purpose (largely urban).

The potential crash contributory factors identified for intersections were:

- **poor sight distance at intersections**
- **confusing alignment of roadway**
- **sun glare (urban only)**
- **unclear vehicle path through intersection (largely urban)**
- traffic signals obscured by poles/trees/signs, etc. (urban only)
- traffic signals poorly laid out (urban only)
- traffic islands poorly located
- inappropriate speed limit (largely rural)
- road pavement poorly maintained (urban only).

The potential crash severity factors identified for intersections were:

- **poles within clear zone (largely urban)**
- **guard fencing not provided (rural only)**
- trees within clear zone.

Lastly, it is important to note that while some of the factors listed above will pose more of a problem to heavy vehicles than other vehicles (e.g. narrow road pavements), in many cases, the crash factors identified probably also contribute to crashes that involve other types of vehicles.

6.1 Case Studies

6.1.1 Site 1 (Road Pavement too Narrow)

This urban intersection is on a straight and level section of road. All crashes occurred in fine weather on a dry road and in daylight hours. Eighteen of the 24 heavy vehicle crashes at this location were ‘same direction sideswipes’ where the heavy vehicle was the colliding vehicle. It appears that a typical crash scenario involved the heavy vehicle (travelling south) attempting to turn left from the major arterial into the more minor road (Figure 6.1).

Taken together, these factors suggest that heavy vehicles may frequently cross into the centre lane, so as to gain more turning space.

One of the major road engineering issues at this site, as indicated by the crash pattern described above and the site inspection, may be lane width. Wider lanes would decrease the probability of sideswipes by affording greater turning space for heavy vehicles turning left off the major arterial. Alternatively, it may be beneficial to consider restricting truck access to the intersecting road if an alternative truck route is practical.

Figure 6.1: Site 1

6.1.2 Site 2 (Unclear Vehicle Path through Intersection)

Sixteen of the 21 heavy vehicle crashes at this urban intersection were rear-end crashes, typically the heavy vehicle was the colliding vehicle. All of these crashes occurred on a straight and level section of road in fine weather on a dry road and during daylight hours. The posted speed limit at the site is 60 km/h. Site inspections revealed a lack of delineation through the intersection (Figure 6.2). Conceivably this could result in drivers braking suddenly when they become uncertain of an appropriate path through the intersection, and being struck by a following vehicle. Trucks may be over-represented among colliding vehicles in rear-end crashes at this site due to their poorer braking performance.

Figure 6.2: Site 2

6.1.3 Site 3 (Unsatisfactory Re-entry to the Carriageway from Private Driveways, Narrow Pavement)

This site is an urban mid-block section with ten of the 20 crashes recorded as occurring at a driveway or median opening. In nearly all crashes, the heavy vehicle was the colliding vehicle. The majority of crashes were either same direction sideswipes or rear-end. All of the crashes occurred on a straight section of road in daylight and under fine weather conditions on a dry road. The posted speed limit is 60 km/h.

Half the crashes occurred near driveways or median openings, which suggests that there may have been issues related to uncontrolled entry and crossing along this busy stretch of road. The site inspections confirmed this, revealing many private access points which must be negotiated at very slow speeds for both access to and egress from the main road. The poorer braking of heavy vehicles in particular may have been exacerbated by the fact that this road segment is on a slope. In addition, the incidence of sideswipes might suggest inadequate lane width for heavy vehicles, site inspections confirmed that lane width was approximately three metres on some parts of the segment.

There is also loose material present on the driveway depicted in Figure 6.3. This has the potential to reduce the acceleration capabilities of a stopped vehicle and, if it is tracked onto the through carriageway, it poses a skid resistance risk for heavy vehicles.

Figure 6.3: Site 3

6.1.4 Site 4 (Trees in Clear Zone)

There four run-off road crashes at this rural midblock. All crashes involved an articulated truck and all occurred on a bend in dry conditions. Three of these crashes occurred in either darkness or at dusk. Site inspections revealed good curve delineation and the presence of audio tactile edge lining (although the value of this for heavy vehicles is unclear). Signage located at the site indicated that it has been identified as a high risk zone for heavy vehicles which were advised to adhere to advisory speed limits on curves, but some large trees were present within the clear zone at some of the bends (Figure 6.4). Although clear zone hazards do not cause crashes, they can result in more severe run-off road crashes, and for this site the presence of trees within the clearzone were considered to be a potential crash severity factor.

Figure 6.4: Site 4

6.1.5 Site 5 (Limited Sight Distance at Intersection)

Most of the eight crashes at this site occurred when a) an eastbound heavy vehicle collided rear-end with a light vehicle or b) a westbound right turning heavy vehicle collided with an eastbound light vehicle. Six of these crashes occurred on a dry road in fine weather and during daylight hours.

Site inspections revealed that eastbound traffic travels over a slight crest and right curve approaching the intersection (Figure 6.5), which limited sight distance. Further, approaching vehicles could be reliant upon only the upper signal display or braking traffic alone if lower signals are obstructed by traffic (and the approach alignment). These factors may have contributed to the rear-end crashes.

In relation to the right-through crashes, the uphill start for the right turn (across three lanes) could mean that sight distance is likely to be insufficient for a full turn without collision risk to the side of the heavy vehicle.

Figure 6.5: Site 5

6.1.6 Site 6 (Partially Sealed Shoulders, Steep Embankment, Inadequate Curve Delineation)

Ten crashes involving heavy vehicles were recorded at this rural segment. The site is within a medium speed environment with speeds ranging from 60 km/h to 80 km/h. Eight of the crashes involved heavy vehicles leaving the carriageway (the remaining two involved head-on collisions). Six of the off-path crashes occurred at night and all of the off-path crashes occurred on a dry road surface. The majority of the crashes occurred during clear weather and at a curve, and all crashes occurred on a grade.

The site inspections revealed a lack of adequate night time curve delineation at some points, and only partially sealed shoulders, which may have been contributing factors. The presence of steep embankments at the roadside (Figure 6.6) may have contributed to the severity of the run-off road crashes that occurred.

Figure 6.6: Site 6

6.1.7 Site 7 (No Factors Noted)

There were four heavy vehicle crashes that occurred on this short segment (Figure 6.7). Two occurred during darkness, two occurred on a wet road surface and two occurred during the morning peak time. The crash type was different in each case (although all were ‘same direction’ crashes). Site inspections did not reveal any road-related potential crash causation factors while police crash narratives supported the notion that the crashes that occurred at this stretch were not the result of any particular road feature.

Figure 6.7: Site 7

7 ROAD DESIGN AND COUNTERMEASURES

The previous sections of this report have highlighted some facets of the road environment which may require particular attention in improving the performance of Australian freight routes in terms of heavy vehicle safety. The topics covered in this chapter reflect the issues identified during the site inspections and workshop conducted as part of this study (and to a lesser extent, the crash data analysis) that can be addressed through road design.

Guidance on addressing heavy vehicle safety through road engineering is available in the relevant Austroads Road Design or Traffic Engineering Practice Guides and the Austroads Road Safety Audit guide (Section 8). It is also the case that good design for many road elements will be the same for both passenger vehicles and heavy vehicles.

This chapter provides comment on the applicability of existing road design guidelines for heavy vehicles in relation to the issues covered, and where these do not provide coverage, offer some guidance as to how selected issues can be addressed. Harwood et al. (2003) have published a synthesis on ‘highway/heavy vehicle interaction’. This TRB document presents the state of knowledge and practice concerning the accommodation of heavy vehicles on highways and is drawn on substantially throughout this chapter.

7.1 Road Geometry

7.1.1 Sight Distance

Stopping sight distance

The site inspections conducted during this project highlighted sight distance at access points as a potential crash causal factor at a substantial number of crash cluster sites. The TRB synthesis suggests that in terms of stopping sight distance (which should enable a driver travelling in a vehicle at the design speed to see an object and then stop in time to avoid hitting it) heavy vehicles may actually have an advantage at crests (vertical curves). This is because heavy vehicle drivers sit higher than passenger car drivers and therefore can see ‘over’ the crest from further back along the road. It is also true that the larger size of a heavy vehicle may also increase its conspicuity to other road users when entering the traffic stream. This does not apply at horizontal curves however and the Austroads Guide to Urban Road Design (2002a) provide separate values for car and heavy vehicle stopping sight distance.

Overtaking sight distance

The site inspections conducted as part of this project highlighted sight distance for overtaking as a potential crash causal factor at a substantial number of rural crash cluster sites. While sight distance for overtaking is only applicable on two-lane two-way roads, McLean (2002) states that the majority of Australia’s rural and inter-regional road network consists of two-lane two-way roads (with a thin pavement section and narrow [5.5 m to 6.0 m] overall seal width).

The NTC (2002c) report *Performance characteristics of the Australian heavy vehicle fleet* incorporates an Appendix on the issue of vehicle length and overtaking time. It is highlighted that the length of an impeding vehicle affects the time required for it to be overtaken and, hence, the size of gap required for safe overtaking. It is also pointed out that current Austroads (2003a) overtaking sight distance guidelines (to be used in determining overtaking zones on multiple combination vehicle routes) are based on research conducted some 25 years ago following from the ERVL study (Troutbeck 1981) and that since that time the heavy vehicles commonly using two-lane highways have increased in length by more than 50%.

According to the report:

> There do not appear to have been any great overtaking related problems associated with the past increases in heavy vehicle length. Three factors would have contributed to this.
>
> - Driver overtaking gap acceptance behaviour is typically conservative. With each increment in overtaking time being relatively small, errors of judgement will be typically covered by the conservative gap-acceptance decisions and, with time, gap-acceptance behaviour adapts to the increased times.
> - The practice of part sealing shoulders first appeared in the 1970s and became generally accepted during the 1980s. With the additional lateral space provided by a shoulder seal, drivers are prepared to overtake with a greater speed differential thus reducing overtaking times and acceptable gaps.
> - The provision of overtaking lanes to increase overtaking opportunity became accepted practice during the 1980s. On higher volume highways, these have typically balanced the increase in overtaking demand from increasing traffic volume, heavy vehicle proportion and heavy vehicle length (p. 197).

It appears that, at present, existing guidelines for overtaking sight distance should adequately account for the current heavy vehicle fleet.

Intersection sight distance is covered in Section 7.3.

7.1.2 Lane Width

The Austroads (2002a;2003a) Urban and Rural Road Design Guides suggest that the minimum lane width proscribed therein (3.5 metres) is appropriate for most freight efficient vehicles, although some larger vehicles such as the A-triple may require lanes of 3.7 metres. The Austroads guidelines regarding lane width are based on a 1999 report by Prem et al. (1999) who used computer modelling (validated by full-scale tests of the tracking behaviour of an A-double) to determine the required lane widths for a range of heavy vehicle configurations. The aim was to determine dimensional limits on tracking for heavy vehicles following a straight path that would cover situations that might occur under the existing mass and volume loading schedules. According to this work, heavy vehicle tracking performance was principally dependent on cross-slope profile, vehicle length and configuration and speed, and all but two vehicle types could travel comfortably on roads with a usable lane width of 3.5 metres. A-triples and rigid-plus-three vehicles operating at 90 km/h (the highest speed tested) could not, and thus the Austroads guidelines acknowledge the need for 3.7 metre lanes in some circumstances.

It should also be noted that ability of a heavy vehicle to travel safety within certain lane widths is also influenced by the width of the shoulder and if the shoulder is sealed.

Recent work conducted in Queensland (Lennie & Bunker 2005) showed that approximately 5% of drivers leave the marked lane when travelling adjacent to a semi-trailer or B-double on multi-lane roads. They conclude that if this behaviour is shown to be dangerous road design guidelines may need to account for this indirect relationship between heavy vehicles and lane width requirements.

7.1.3 Shoulder Sealing

The crash data analysis conducted as part of this project suggests that the predominant category of heavy vehicle crashes on rural roads is run-off-road (ROR) crashes (about 30% of rural crashes for rigid trucks and 40% for articulated trucks, less for buses). Run-off-road crashes were less predominant in urban contexts but still comprised about 10% of heavy vehicle crashes. Previous Australian work has supported the finding that approximately one-third of rural heavy vehicle crashes are run-off-road (Australian Transport Safety Bureau 2004). Significant proportions of ROR crashes occur due to the poor condition of road shoulders on high speed rural roads (and this study indicated that partially sealed shoulders were present at a substantial number of crash cluster sites).

In general, the road shoulder can be used by errant vehicles as a recovery area, allowing such vehicles to regain control and ultimately avoid a run-off-road crash. Generally, this can only occur when the shoulder is sealed, and provides similar friction levels as the road pavement, with minimal vertical discontinuities between the road pavement and the shoulder pavement. A number of Australian rural crash studies in the 1980s found that shoulder type and condition were significant factors in ROR crashes. Armour et al. (1989) for example, found that over 30% of single vehicle rural crashes (and not heavy vehicle crashes specifically) commenced with the left wheels of the vehicle moving onto the shoulder, the driver over-corrected to regain position on the seal and losing control of the vehicle, typically running off the road to the right. Degraded shoulder condition, including excess loose material or steep edge drop-off was considered to be a contributory factor in many of these crashes.

Similar patterns have been identified in other Australian crash studies (e.g. Catchpole 1989; King 1986). The behaviour of errant vehicles on unsealed shoulders has been investigated at length by Glennon (1987), who reviewed and interpreted research findings available up to 1984. The research largely comprised trials using professional drivers and computer simulation studies which had identified a hazardous situation referred to as the ‘scrubbing re-entry’. Scrubbing re-entry crashes occur when the steer wheel on the shoulder side, having left the pavement, 'scrubs’ along the drop-off. Additional steer angle is applied until ultimately the vehicle yaws to the right and proceeds to travel across the roadway. Heavy vehicles frequently become involved in such crashes when an oncoming vehicle encroaches onto the shoulder, presumably to provide greater separation between it and the oncoming truck.

In Australia and New Zealand the majority of high speed rural roads consist of sealed-surface lanes, and unsealed shoulders, with crushed stones often used as the unsealed shoulder surface (McLean 2002). This practice can be extremely hazardous to heavy vehicles, as the width of such vehicles can result in their encroaching onto the road shoulder area. Additionally, where narrow seals are used in combination with high heavy vehicle volumes, the trailing vortices from heavy vehicles can erode the pavement binding material, thus turning shoulder edges into gravel. This can create edge ‘drop-offs’ which can promote ROR crashes. Poor road shoulder condition is depicted in Figure 7.1.

Source: P. Robinson

Figure 7.1: Poor road shoulder condition

There have been many local studies which indicate the effectiveness of road shoulder sealing initiatives in terms of crashes involving all vehicle types. The effects of improvements centred around the installation, sealing and widening of roadside shoulders was reported in the *LTSA Shoulder Improvements* report (1995). The investigation included 41 open road routes in New Zealand with a speed limit of greater than 70 km/h, and revealed that general shoulder treatment improvements resulted in:

- a 55% reduction in loss of control crashes on straights
- a 36% reduction in loss of control crashes on bends
- a reduction of 61% in overtaking crashes.

Overall the study found that there was a 37% decrease in all crash types on open road routes where the condition of shoulders was improved.

Corben et al. (1997) conducted extensive studies into the effects of Victorian blackspot programs. A total of 254 state and federally funded blackspot treatment programs covering the period 1989-1994 were investigated. It was found that large scale shoulder sealing reduced casualty crashes by 32%. Ogden (1995) conducted a study of shoulders of no less than 600 mm of seal beyond the traffic lane edge line on Victorian rural highways (two-way rural roads). Based on crash data for the period January 1983 – December 1991 Ogden concluded that sites with sealed shoulders experienced a 43% lower crash rate (casualty crashes per million vehicle kilometres of travel) after the shoulder was sealed, compared with control sites. Similar figures were reported by McLean (2001), who stated that 40% crash reduction rates were recorded in Victoria. Furthermore, McLean commented on international experience with regards to shoulder sealing, and stated that a 1.0 to 1.5 metres hard shoulder seal would virtually eliminate heavy vehicle wheel encroachments beyond the seal edge, and thus reduce the damaging effects of trailing vortices as described earlier.

Of the Corben et al. (1997) findings, a total of 160 blackspots were investigated for benefit-cost ratio. Of these sites, 36 had large scale shoulder treatments applied, and the benefit-cost ratio was calculated to be 6.5. This is quite high compared with the average ratio of 4.1 calculated for all treatments, indicating that in this instance, shoulder treatments represent a cost-effective crash countermeasure. Ogden (1992) studied crash reduction rates on two lane rural highways in Victoria following the implementation of shoulder sealing treatments, and reported that a benefit-cost ratio of 2.9 x the AADT (annual average daily traffic, in thousands of vehicles) was calculated.

Despite the apparent safety benefits offered by improving or installing road shoulders, it is noted that their implementation should be carefully monitored. McLean (2001) notes that past research has indicated that crash rates can actually increase on two lane roads with sealed shoulder widths greater than 2.5 metres. This is reasoned to be due to the fact that drivers will treat the shoulder as an additional lane. Further, widened shoulders, especially if sealed, have the potential to increase the speed of heavy vehicles (e.g. Figueroa Medina & Tarko 2005).

Within the range of normal Australian design practice, crash reductions from shoulder seals are typically in the range 30 to 40%, with the majority being ROR crashes. The reductions are due to an improved initial zone for the recovery of errant vehicles and the elimination of crashes arising from the ‘scrubbing re-entry’ problem described earlier. In general, road shoulder sealing is one of the most widely understood crash countermeasures, and has a great deal of applicability to heavy vehicle safety.

7.1.4 Roadside Hazards

The site inspections conducted as part of this study revealed that roadside hazards, including poles, trees, steep embankments and unprotected culverts were present at a considerable number of the heavy vehicle crash cluster sites inspected.

Collisions with roadside hazards are a major cause of fatality and serious trauma for ROR crashes occurring in rural areas. Sweatman et al. (1990) reported that roadside hazards contributed to about one-third of fatal truck crashes.

The national standards for roadside design for new roads suggested by McLean (2001) in his study on cross-sections for new roads, give a maximum target clear zone width of nine metres (for one way AADT greater than 6000, and for tangents and the outsides of curves greater than 1,000 metres). However, in the same study, McLean acknowledges that the retrofitting of clear zones on existing roads is generally constrained by the pre-existing conditions of the roadside. In this case, McLean suggests that the aim be for the maximum possible that can be reasonably achieved, with a clear zone width of four metres to five metres capturing most of the roadside safety benefits of wider clear zones. The adequacy of these conclusions in terms of heavy vehicle safety is unclear.

The removal of the risk posed by roadside hazards can be achieved through a number of means including:

- removal of the hazard
- relocation of the hazard to a safer location
- alteration of the hazard to reduce impact severity
- install impact attenuation or redirection devices to guard the hazard.

The first two listed treatments, the physical removal/relocation of the hazard, can often be the most effective. However, in the case of trees and poles (two objects that were identified as present at a number of the crash cluster sites inspected) careful consideration must be given to feasibility, particularly from an economic viewpoint.

The alteration of the hazard in most cases also provides an acceptable solution, and can be achieved in the form of various innovative designs. For example, light poles have been designed which absorb energy on impact, thus lessening injury to vehicle occupants and culvert end walls can be made 'driveable' (Figure 7.2).

Figure 7.2: Driveable culvert

However, this cannot be achieved in the case of trees, for example. In such cases, crash barriers have the potential to achieve risk reductions. Heavy vehicles are heavier and have a higher centre of gravity than passenger vehicles (this latter characteristic makes them more susceptible to rollover, Ogden, 1992) and so it cannot be assumed that a barrier system effective for passenger vehicle crashes will also be effective for heavy vehicles. Jacques et al. (2003) reviewed published and unpublished literature on the performance of safety barriers in relation to heavy vehicle crashes to reveal that:

> Concrete barriers – penetration of the barrier appears to be relatively low risk, while the risk of vehicle rollover and unstable redirection of the vehicle are of concern;
>
> Steel guardrails – penetration of the barrier is more probable than for concrete barriers, whereas the more forgiving structure of these semi-rigid barriers reduces the risk of rollover, given no difference in roadside slope or other physical features;
>
> Flexible barriers – successfully contain, in controlled tests, an errant heavy vehicle at lower impact angles and speeds [70 km/h] thereby also reducing the risk of the vehicle penetrating the barrier. Flexible barriers may also reduce the risk of vehicle rollover and unstable redirection of the vehicle when compared to more rigid barriers. The flexible barriers also appear to lower the risk of injury to the occupants of the striking vehicle (p. VI).

Some United States highways agencies (and Australian road authorities) have used traffic barriers specifically designed to contain heavy vehicles, such as tall concrete barriers and super heavy-duty guardrails at the bottom of long downgrades (Harwood et al. 2003) but Jacques et al. (2003) note a lack of conclusive, reliable evidence about the performance of major barrier types in heavy vehicle crashes. Therefore, while crash barriers may be an effective means to reduce the risk of roadside hazards for heavy vehicles, specifically designed barriers, or the removal of roadside hazards, would be a more reliable overall strategy for high risk freight routes, at least in terms of safety.

Impact attenuators

An impact attenuator (or crash cushion) moderates the deceleration forces which occur during a high-speed impact involving a vehicle and a fixed object, usually by means of an energy absorbing material which serves to increase the impact time, and subsequently, decrease the deceleration forces experienced by the vehicles occupants. Types of impact attenuator include sand-filled plastic barrels, water-filled tubes, foam-filled cartridges, aluminum tubes, and steel drums.

These devices do not prevent collisions with the object they are installed around thus should not be confused with rigid or flexible guard systems. Common industry practice is that impact attenuators should be used as a 'last resort' in all cases (the most preferred option being the removal or relocation of the fixed object). In cases where this cannot be achieved, (such as the ends of guardrails on freeway exit ramps and median barriers), on bridge piers in narrow medians, median barrier terminals, bridge rail ends, impact attenuators have been used.

The Australian experience with impact attenuators is not particularly detailed with regards to the evaluation of such measures but impact attenuators have been included on many Australian freeways and highways. Common types of permanent crash cushions complying with ASNZ 3845:1999 are shown in Figure 7.3.

Source: VicRoads (2005)

Figure 7.3: Crash cushions

As the majority of vehicles on Australian roads are passenger vehicles, it follows that most impact attenuators are designed to provide safety benefits for these vehicles and their occupants. They are unlikely to prove as effective at reducing the severity of impacts involving heavy vehicles. As such, impact attenuators intended to reduce the severity of heavy vehicle crashes will need to be designed especially for this purpose at sites deemed to have a high risk of heavy vehicle crashes. Unfortunately, the space required to dissipate the kinetic energy and gradually decelerate a large heavy vehicle is likely to be excessive for most highway applications (AASHTO 2002).

7.2 Traffic Control Features

7.2.1 Signage

The site inspections conducted during this study indicated that hidden or inconspicuous signage and/or traffic signals which were obscured by poles, trees or signs were present at a considerable number of crash sites. The solutions to these issues (e.g. removal or relocation of the obstruction or relocation of the sign or signal that is obscured) should be the same irrespective of whether heavy vehicles or light vehicles are considered.

The site inspections also noted insufficient signing as an issue, including advisory and warning signage. Traditional and most commonly used methods of warning approaching traffic of potentially dangerous roadway features include static warning signs such as advisory speed and chevron markers. Although in many cases the signage requirements of heavy vehicles and passenger vehicles will be the same, static signs can be used to convey heavy vehicle specific messages as depicted in Figure 7.4 through Figure 7.6. The Tilting Truck sign is designed for use where there is a history of trucks toppling despite the provision of all other required curve warning and delineation devices. It is normally associated with, and placed in advance of, a curve or turn warning sign. The Trucks Use Low Gear sign is used in conjunction with the warning sign Steep Descent at the top of long and steep downgrades. The Trucks (Crossing or Entering) sign should be used where it is necessary to warn that trucks may cross or enter the road from an adjoining property (Standards Australia 1994).

Source: Standards Australia (1994)

Figure 7.4: The tilting truck symbol

Source: Standards Australia (1994)

Figure 7.5: Trucks use low gear sign – right

Source: Standards Australia (1994)

Figure 7.6: Trucks (crossing or entering) sign

More recently, active warning signs have been used to improve heavy vehicle safety. Active warning signs utilise technology to make real-time judgements of potential hazards, and subsequently inform the driver of these hazards so they can take corrective action. These systems operate using sensor-based technology which monitors environmental conditions, road conditions, or vehicle operating characteristics (such as speed or mass), makes judgements based on this information and advises drivers of potential hazards via a variable sign or a flashing beacon. Potential areas for application of active warning signs include:

- warning road users of inappropriate approach speed for oncoming roadway features such as curves or steep down grades.
- warning road users of the presence of ice or slippery roadway conditions.

Such active warning devices have particular applicability to heavy vehicles at freeway entry and exit ramps as it has been suggested that negotiating entry and exit ramps is a particularly difficult task for heavy vehicle drivers, and inappropriate speeds at these locations can result in vehicle rollover. Some examples of active warning signs presented in Harwood et al. (2003) are summarised below:

- In Texas infra-red light-beam sensors have been used to determine truck speeds, height, and length. When a truck exceeds the maximum safe speed for that curve a static warning sign with flashing yellow beacons is activated.
- In Virginia and Maryland a curve warning system uses weigh-in-motion detectors, loop magnetic detectors (speed) and radar sensing height detectors to warn drivers, via flashing signals mounted above truck rollover signs, when their vehicles' rollover threshold is approached.
- In Colorado loop detectors, weigh-in-motion devices and a variable message sign have been used to present to drivers a grade descent speed safe for their vehicle's axle configuration and weight.
- In Oregon, high-speed weigh-in-motion devices and automatic vehicle identification devices recognise in-truck transponder signals and interact to produce a customised message (which can include the driver's name) on a roadside variable message sign which states a safe descent speed for that truck on that hill.

An active warning device is presently installed on the interchanges of a tollway and a freeway in metropolitan Melbourne, implemented due to the occurrence of several heavy vehicle rollovers at these locations but the use of this technology in Australia is fairly recent and there is little available data which can be used to quantify its benefits. International research, however, has indicated the benefits of such systems (e.g. Hanscom 1987; Janson 1999).

7.2.2 Delineation Devices

The site inspections conducted as part of this study indicated that 'unclear vehicle paths' existed at a substantial number of the crash cluster sites inspected. Naturally occurring information regarding roadway delineation can be enhanced through specifically engineered delineation devices (often referred to as 'formal' delineation) which serve to define the roadway operating area for the road user. These engineered devices can be classified as 'long range', which provide information relating to course planning and navigation, or 'short range', which aid the driver in local path tracking. Driving in conditions of high visibility, natural cues are often sufficient to provide information to the driver regarding roadway delineation. However, in situations resulting in poor visibility, such as night or wet weather, delineation devices can be the sole provider of delineation information and as a result, are a crucial element of road safety.

Given that heavy vehicles have longer stopping distances, less manoeuvrability and stability than passenger vehicles, and are often required to travel along high speed rural highways at night and in conditions of poor visibility, adequate delineation is vital to ensure the safety of these road users. There is also a body of evidence which states that road delineation measures, which have particular importance for fatigued drivers, have even higher importance for heavy vehicle drivers, as these drivers are prone to driving when fatigued, due to factors inherent in their profession.

Sweatman et al. (1990) analysed heavy vehicle crash data from New South Wales highways (Hume and Pacific) in 1988-1989 and showed that 25 out of 83 (30%) heavy vehicle crashes may have been prevented by improved road delineation. It is also suggested that the use of audio tactile edge lining (or rumble strips) could have resulted in a reduction of up to 22% of the crashes.

The use of formal delineation methods in Australia and New Zealand has occurred for many decades, and despite documented benefits Carnaby (2004) notes that a very small proportion of state road authority road improvement budgets is spent on delineation. Common methods of conveying delineation information include:

- pavement markings – these can be either painted or of a rigid thermoplastic construction, and are used most commonly to indicate lane centrelines and edges
- curve alignment markers – referred to most commonly as 'chevrons' or CAMs, and used to indicate the presence and direction of curves in the roadway
- raised pavement markers – most commonly, these are retro-reflectors which reflect the headlights of the vehicle to augment the delineation provided by painted pavement markings (retro-reflective pavement markers were noted to be absent at a number of rural crash cluster locations where they may have provided safety benefits)
- audio-tactile edge-lines – includes 'rumble strips' and raised or rippled edge-lines, which aim to target fatigued drivers by providing an audible warning if contacted by vehicle tyres
- post mounted delineators – serve the dual purpose of marking out road curves and retro-reflection.

Baas et al. (2004), in a report titled: *Review of lane delineation* for Transport New Zealand provides an exhaustive review of current and past literature relating to the national and international use of roadway delineation measures. The review reported considerable variation regarding reported effectiveness. The report cites the following findings from the researched literature:

- Centrelines on roads had been found to reduce crash rates by between 1% and 65%.
- Edge-lines had been found in some studies to have no effect on reducing crash rates, while some had reported up to an 80% reduction in crash rates.

- Wider than normal edge lines had generally resulted in an average decrease in crash rates of 48%.
- Shoulder rumble strips was found to have reduced ROR crashes by between 22% and 80%.
- Centreline rumble strips have been found to reduce head-on and sideswipe crashes by between 21% and 37%.

The body of literature regarding the effectiveness of delineation devices indicates benefits. However, Baas et al. (2004) notes that evidence also suggests that the success of delineation measures is highly dependent on the local conditions. Further consideration is also required for the suitability of retro-reflectors and audio-tactile edge-lining as delineation measures for heavy vehicles specifically.

Tan et al. (1996) and Douglas (2000) note that the performance of retro-reflectors (including pavement mounted and post-mounted) is influenced by the observation angle (between the line of sight and the line connecting the source and the retro-reflector). The fact that heavy vehicle drivers sit much higher than passenger vehicle drivers means they have differing observation angles, and as a result, heavy vehicle drivers may only receive benefits from long-range delineation and may not see short-range delineators as well as the drivers of passenger vehicles. Cairney (1993) indicates that informal tests show that post-mounted delineators viewed under ‘high beam’ light from a heavy vehicle appear similar to post mounted delineators viewed under ‘low beam’ light from a passenger vehicle. Sivak, Flannagan and Gellatly (1993) examined reflective sign legibility at points reasonable for sign detection (152 metres) and legibility (305 metres). At 305 metres the light reaching a heavy truck driver was as low as 68% of that reaching a car driver (depending on sign position) and at 152 metres the light reaching the truck driver was as low as 25% of that reaching the car driver. Sivak et al. concluded that the increased eye height of truck drivers has a substantial impact on the legibility of retro-reflective signs (and a modest effect on their detection) and that reduced observation angles for truck drivers or inherently more efficient retro-reflective sign materials would alleviate the potential problems.

In a similar vein, it has been suggested that the effectiveness of audible delineation devices is reduced for heavy vehicles, and as such, the benefits received by heavy vehicle drivers are reduced. Cairney (1994) obtained both subjective and objective measures of cabin noise levels in a semi trailer as it traversed thermoplastic audible edgelining of 8 mm height. These noise levels were compared to those produced during travel within the lane. Noise levels while traversing the edgelining were 4dB higher at 100 km/h and with the truck carrying a load. The differences were smaller at lower speeds and when the truck was unladen. Subjective measures indicated that it was not always possible to hear the audible edgelining from within the cabin of the truck.

Cairney, Cusack and Ford (1997) used a similar method to that employed by Cairney (1994) to test four types of audible edgelining:

- Edgeline Auditory Markers (ELAMs)[7] at 1.0 m spacing
- ELAMs at 1.5 m spacing
- ELAMs at 2.0 m spacing
- Audio Tactile Edgeline at 150 mm spacing.

Cairney et al. (1997) found that truck drivers expressed a clear preference for ELAMs at 1.0 m spacing but rated both this treatment and ELAM’s at 1.5 m spacing more favourably than the other treatments in terms of both noise levels and vibration.

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[7] ELAMs are plastic bars 150 mm wide by 50 mm long by 12mm high.

The California Department of Transportation (2001) recorded sound levels inside the cabin of passenger vehicles and heavy trucks for comparison to readings while traversing both a rolled shoulder rumble strip (SRS) and a milled SRS[8]. Testing revealed an increase in average auditory stimulus ranging from 11.0 – 19.9 dB for passenger cars at test speeds of 80 and 100 km/h. Heavy trucks produced less auditory stimulus when measured inside the cabin, ranging from an average of 1.8 dB – 4.7 dB. However, due to a space constraint at the testing facility, heavy trucks were only tested at speeds of 80 km/h. Four accelerometers were mounted to the steering wheel of test vehicles to test for vibrational stimulus. A general trend was found in the vibrational stimulus produced, as the depth of the SRS increased, so did the amount of vibrational stimulus. No literature on the impact of thermoplastic shoulder rumble strips on heavy vehicles was identified.

7.3 Intersection Design

The site inspections conducted as part of this project indicated that several facets of intersection design (traffic signal layout, traffic island location, alignment and clear delineation of vehicle path and sight distance) may have played a role in contributing to the crash risk at the site. These design considerations are all covered by the Austroads Traffic Engineering Practice Guidelines (specifically, *Part 7 – Traffic Signals* and *Part 5 – Intersections at Grade*).

According to Harwood et al. (2003) the key considerations that must be taken into account when designing an intersection for safe use by heavy vehicles are:

- Kerb return radii for right turns (left turn in the Australian and New Zealand contexts). Harwood et al. suggest that a balance is required between accommodating the off-tracking and swept path of the vehicle types that use the intersection (without them having to encroach on the kerb or opposing or adjacent lanes) while maintaining reasonable pedestrian crossing distances and minimising disturbance to existing roadside development.
- Available storage length for left turn lanes (right turn lanes in the Australian and New Zealand contexts). Right turn lanes (in Australasia) must be sufficient in length for deceleration, storage and a transition taper. The required length for turning lanes will vary depending on the type and number of heavy vehicles using it. If the lane overflows and queues protrude into the through lanes, safety is compromised.
- Median width. Harwood et al. (1995) suggests that on rural divided roads the median width at unsignalised intersections should be as wide as practicable and should accommodate the length of design vehicles present in sufficient numbers to serve as a basis for design. In urban areas and at signalised intersections, Harwood et al. suggest that narrower medians operate more safely and the selected median width should typically be just sufficient to accommodate current, and anticipated future, right turn treatments required to serve current and anticipated traffic volumes.
- Visibility restrictions due to vehicles in the opposing left-turn lanes (right turn lanes in the Australian and New Zealand contexts). Harwood et al. (2003) suggests that parallel and diagonal offset right turn lanes (Figure 7.7) can be used to mitigate this problem.

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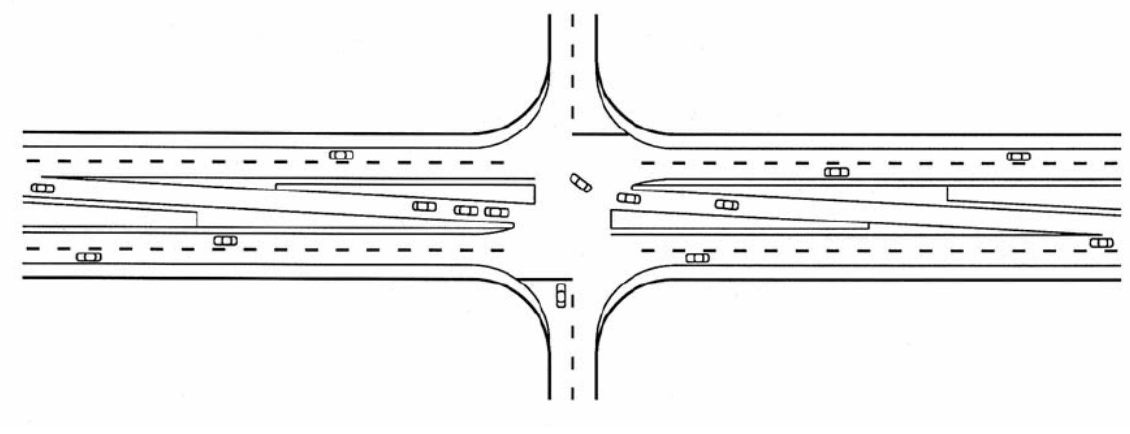
[8] A milled SRS is made by cutting smooth grooves in the roadways. Rolled SRS are pressed into freshly laid asphalt..



Source: Harwood et al. (2003)

Figure 7.7: Parallel and tapered offset right-turn lanes

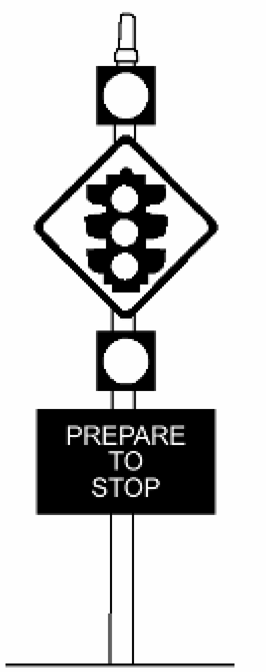
Intersection sight distance

At intersections drivers must be able to view not only the road ahead but also potentially conflicting vehicles on the intersecting roadway in time to stop to avoid a collision. The Austroads guide to Traffic Engineering Practice – Part 5 suggests that Truck Stopping Sight Distance should be provided at intersections:

- on tight horizontal curves (particularly in hilly terrain or near bridge piers)
- on or near crest vertical curves
- at intersections used by a significant volume of large or special vehicles.

It is also advised that Truck Stopping Sight Distance should be applied at underpasses because these pose a risk to large vehicles specifically.

Advance warning signals can be used in advance of intersections to provide additional advance notice to drivers. The Guide to Traffic Engineering Practice – Part 7 suggests that advance active warning signals such as those depicted in Figure 7.8 (and as opposed to passive warning signs) can be used on arterial roads with a high proportion of heavy or long combination vehicles, a high risk of infringement of the intersection signals and a high risk of rear-end or cross crashes due to the inability to stop in time for the red display. They can also be used when the traffic signals are obscured from the view of approaching traffic.



Source: Austroads (2003b)

Figure 7.8: Advance warning signals

The workshop conducted during this project also supported the need to consider heavy vehicles specifically in terms of signal phase timing and sight distance at level crossings.

Level crossings

Level crossings present a similar challenge to other intersections in terms of sight distance. Not only should Truck Stopping Distance be taken into account on the approaches to railway level crossings, it must be possible for a truck driver to start the vehicle from a stop and clear the crossing safely in less time than it takes a train to travel between where it can first be observed by the driver to the crossing. This is reflected in the current Austroads Road Design Guidelines.

The spacing between level crossings and adjacent intersections must also be considered. According to Harwood et al. (2003), locations with short spacing between intersections and rail tracks should be designed so that longer vehicles should not be forced to stop in a position where the rear of the vehicle extends onto the railway tracks, or conversely, the roadway.

Signal timing

Harwood et al. (2003) report suggest that in the U.S. heavy vehicles are often a consideration in selecting the length of a yellow signal phase and assessing the need for an all-red clearance interval at signalised intersections. In Texas a system incorporating truck priority logic, loop detectors and a vehicle classifier has been used to reduce the number of stopping manoeuvres made by trucks but no safety outcomes have been measured.

7.4 Other Issues

7.4.1 Speed Limits

Some of the rural site inspections indicated that the applicable speed limit was higher than is perhaps ideal in safety terms. This suggests that speed limit reductions should be considered at ‘high risk’ rural intersections (and should not be taken to indicate that blanket reductions at rural intersections are appropriate).

In terms of speed limits in general, there is considerable debate about whether differential speed limits for heavy vehicles provide safety benefits. Australian Design Rule (ADR) 65, which came into effect in 1991, requires that for ‘heavy goods vehicles and heavy omnibuses the maximum vehicle road speed capability shall be no greater than 100 km/h’ (heavy goods vehicles are defined as those exceeding 12 tonne gross vehicle mass).

Proponents of differential speed limits such as that required by ADR 65 argue that because heavy vehicles have limited manoeuvring and braking capabilities they should be required to travel at lower speeds than passenger vehicles. Proponents of uniform speed limits suggest that the increased in variance in travel speeds between heavy vehicles and other vehicles may increase traffic conflicts, including those associated with overtaking.

Based on a recent and comprehensive overview (for the TRB) of research on speed differentials between heavy and light vehicles, Kockelman (2006) concludes that the current state of knowledge regarding differential speed limits for trucks does not allow for any definitive conclusion regarding the associated safety benefits, or harm.

7.4.2 Pavement Surface

The surface at some of the urban crash cluster sites was noted as being poorly maintained. At intersections or areas where curves, elevation changes and high speed are combined, skid resistance is likely to present as an issue. At other points along the road, rutting and potholes are more likely to be of concern.

Skid resistance

The ability of a driver to maintain control over their vehicle is greatly influenced by the friction available between vehicle tyres and the road surface. Braking, steering and acceleration are all dependent upon road surface friction. While road surfaces should generally have adequate levels of surface friction, in areas where loss of control crashes are prevalent, high-friction overlays can be introduced onto the road surface as a crash countermeasure. With respect to heavy vehicle specific crashes, loss of control is typically an issue in two areas:

- Highway interchanges (exit and entry ramps), as these areas often include a combination of tight-radius curves, elevation changes, and high vehicle speeds, the combination of which can lead to high friction demand
- signalised intersections, as the incompatible decision making between drivers of passenger and heavy vehicles when faced with a red or amber light can lead to heavy vehicle emergency braking, and if there is insufficient road friction, loss of control. This issue is further exacerbated by the fact that heavy vehicles, as a general rule, have poorer braking performance when compared to passenger vehicles (at least under dry conditions).

Many studies have shown that skid resistance decreases with length of pavement service time for all types of pavements, although some pavements demonstrate better performance in this area than others. It has also been noted that there is a relationship between the decreasing level of skid resistance and high heavy vehicle traffic volumes, potentially due to the considerably higher axle group loads and subsequent increased level of pavement horizontal loading. There is also evidence (Gillespie 2002) which suggests that pavement locations where vehicles require the greatest skid resistance can suffer the greatest ‘polishing’ effect.

As stated by Parfitt and Lewando (2005) there are no officially recognised specifications for high friction treatments in Australia and New Zealand but a recent UK skid resistance policy based on 15 years of data and experience establishes desirable, investigatory, and minimum friction levels for paved highway surfaces, and is considered a ‘best practice’ approach within the industry (Sinhal 2005).

In a recent Austroads publication titled *Guide to the Management of Road Surface Skid Resistance* (2005d) it is advocated that strategies be developed by road authorities to manage skid resistance, through recently developed measurement techniques to identify potential problem areas and proactively implement improvement programs. The guide also aims to provide a framework to aid in the implementation of such programs.

Investigations into the effectiveness of applying high-friction surfaces to problem areas have shown crash reductions of more than 50% (Corben et al. 1997; Gillespie 2002) and cost/benefit ratios of greater than 4:1 (Corben 1997; Torpey et al. 1991).

Some of the most convincing recent research into the benefits of high friction overlays has come from New Zealand. Hudson and Mumm (2003) report on crash data for a 20 year period on a road near Wellington. The road section investigated was 1.9 km long, and had steep grades and tight radius compound curves for most of its length, and carried an AADT of 9,800 vehicles in 2003. Two separate surface treatments were investigated from 1980 to 1997, the first being porous asphalt, and second being calcined bauxite. The study concludes that a dramatic reduction in crashes was experienced following the application of calcined bauxite, and suggests a benefit cost ratio of 6 for this countermeasure.

Even though much has been learned about the application of high friction overlays since their introduction over two decades ago, their applicability to the heavy vehicle fleet is still being questioned. Further, Iskander and Stevens (2005) note that while the use of high friction surfaces has proven effective in some instances, effectiveness in heavily congested areas where aggressive driver behaviour is prevalent could be limited.

Rutting/Potholes

Elvik and Vaa (2004, p. 411) suggest that:

> Ruts, cracks and unevenness in the road surface reduce driving comfort and can be a traffic hazard. Water collecting in ruts in the road surface increases the danger of aquaplaning. Ruts and cracks in the road surface may make it more difficult to keep a motor vehicle on a steady course. Large holes in the road surface can damage vehicles and lead to the driver losing control of his vehicle.

Elvik and Vaa also state that there is little research on the link between road surface quality and crash risk. Based on their review of the few relevant studies they conclude that despite the absence of a statistically significant relationship, a weak trend toward an increase in crashes is apparent following the re-asphalting of roads and other improvements in road surface. This may be due to the increases in driving speeds which tend to accompany smoother road surfaces (e.g. Cleveland 1987; Cooper, Jordan and Young 1980).

Cairney and Gunatillake (2001) investigated the link between crash occurrence and resurfacing at 12 Melbourne intersections. Based on crash data for three years before and three years after resurfacing it was revealed that the number of casualty crashes remained unchanged following resurfacing at two sites, increased slightly at one site and fell at eight sites to produce an overall reduction in crash frequency and crash rate. This reduction was equivalent to 0.7 crashes per year per site.

No published work on the relationship between road surface condition and heavy vehicle safety specifically was identified.

7.4.3 Rest Areas

Driver fatigue amongst the heavy vehicle fleet is a considerable issue, and the opportunity for a heavy vehicle driver to safely pull off the road and rest, as well as attend to any mechanical or load restraint issues is considered important for overall road safety. The fatigue problem is highlighted by Williamson et al. (2000), who reported the results of a national survey relating to driver fatigue in the long distance road transport industry. According to the survey, fatigue was a substantial personal problem for 30% of drivers, while the majority also indicated that fatigue was recognised as a considerable problem for the industry.

Recently the National Transport Commission (NTC) commissioned ARRB Group to complete a set of guidelines governing the frequency, location and provision of facilities for rest areas intended for use by heavy vehicle drivers. This initiative acknowledges the lack of consistency and incidence of rest areas provided, and highlights the issue of fatigue management and provides a good indication of the level of concern which this issue has caused amongst the industry.

The NTC (2005) describes three categories of rest area: major rest areas, minor rest areas and truck parking bays. According to the findings of this report, the following features should be present at all major and minor rest areas:

- shaded/sheltered areas
- rubbish bins
- separate parking areas for heavy and light vehicles
- tables and/or benches.

It was advised that truck parking bays, at a minimum, should include the following:

- shaded/sheltered areas
- rubbish bins
- all weather pavements.

Although there is a general agreement that the provision of rest areas on highways and more specifically, freight routes, has a beneficial effect on highway safety, little supporting empirical evidence is present in the literature. The ‘thrust’ for the provision of rest areas on Australian roads stems from the realisation amongst the industry that driving while fatigued poses a significant risk, and rest areas have the potential to reduce that risk.

There is little local data specifically on the reduction in crash rates expected to follow the provision of rest areas and most evaluations are based on an assumption that rest areas reduce fatigue related crashes. While the reduction in driver fatigue is potentially the main benefit to arise from the implementation of truck parking areas, it is not the sole benefit. An NCHRP report (King 1989) describes an investigation into the possible causal chain between highway rest areas and highway safety, and lists other possible benefits that the provision of rest areas allow including reductions in:

- driver inattention related crashes
- shoulder stop related crashes
- vehicle or load related crashes
- adverse driving condition (wet weather, poor visibility due to fog) related crashes.

It can be reasoned that the provision of rest areas could result in reductions in all of these types of crashes but it is difficult to attribute crash reductions to rest areas (Case et al. 1969).

Taylor et al. (1999) revealed that a relationship existed between the average distance between rest areas on certain highways and the percentage of all crashes involving a single vehicle. The research showed that the greater the spacing between rest stops, the higher the percentage of single vehicle truck crashes. This correlation was strengthened by the fact that the same relationship was observed for four separate interstate routes, indicating clearly that frequent rest stops are associated with reducing single vehicle truck crashes. Overall the report concluded that there was a significant increase in single vehicle truck crashes when the distance between rest areas exceeded 30 miles (48 kilometres).

Due to the difficulty in establishing correlations between rest stops and crash rates, cost benefit ratios are rare, and more importantly, potentially misleading due to the lack of good quality input data. Of all reviewed literature, only one cost-benefit analysis was found. King (1989) states that quantifiable benefits for the US Interstate rest area system include a reduction in shoulder stop crashes, user comfort and convenience, and a reduction in excess travel to obtain services. The resulting system-wide benefit-cost ratio was reported as being between 3.2 and 7.4. It should be noted, however, that only one of the quantifiable categories in this instance, reduction in shoulder stop crashes, is directly related to the issue of road safety.

Many researchers have commented on the fact that rest areas, like seatbelts, are only effective in achieving their aims if they are used effectively. The provision of suitable and frequent rest areas specifically designed for use by heavy vehicles will not ensure that the local road network will be free from fatigued drivers. This is due to the fact that the provision of rest areas as a crash countermeasure does not address the cause of fatigued drivers, which can be due to job specific pressures such as deadlines and extended or continual periods of uninterrupted work.

It has also been suggested that vehicle merging related crashes could potentially increase as a result of the provision of frequent rest areas, as this would increase the occurrence of vehicle merging manoeuvres. However, this must be balanced with the fact that merging from the shoulder is likely to be more dangerous than merging from a properly designed rest area.

7.4.4 Service Roads

One of the issues noted during the urban site inspections was re-entry to the carriageway from service roads. The safety problems at such sites will occur largely due to the speed differentials between entering traffic and through traffic. Trucks may be particularly impacted by this due to their longer stopping distance (at least in dry conditions) and their slower acceleration. McLean, Tziotis and Gunatillake (2002) provide speed profiles for a semi-trailer on various constant grades which reveal, for example, that on a 2% upgrade it can take a semi-trailer starting from rest almost a kilometre to reach 60 km/h. Further, as mentioned in Section 7.1.1, downgrades increase the stopping distance of heavy vehicles substantially more than they impact the stopping distance of passenger vehicles.

Together, these factors highlight the need to avoid, where practical, locating service road access-exit points likely to be used by significant volumes of heavy vehicles on steep grades.

7.4.5 Arrester Beds, Escape Ramps and Parking Bays

Although steep grades were not identified as an issue during this project, the need for safe and effective means of overcoming the problem of runaway trucks on long or steep declines has been the subject of considerable research in recent times. One of the most popular solutions at present is the construction of a truck ‘arrester bed’ or escape ramp in a known or predicted problem area.

The terms ‘arrester bed’ and ‘escape ramp’, essentially refer to similar facilities, and aim to achieve similar outcomes using slightly varying methods. An escape ramp consists of an area of suitable width and length of considerable geometric variation which a truck can use to reduce its speed and safely come to a stop in the event of brake failure. An arrester bed also consists of an area of suitable width and length which can be safely accessed by the errant vehicle, but instead of an upgrade, it contains a layer of energy absorbing material which dissipates vehicle momentum in a safe and controlled manner. In ‘on-road’ situations, these two approaches can be combined to form four specific solutions to errant trucks, as defined by Austroads (2003a):

- Sand piles – a large pile of sand is used as the medium for the dissipation of vehicle momentum. Due to the severe deceleration qualities of the sand, this solution is usually only used where space is limited.
- Descending/horizontal/ascending grade – a specific aggregate material is laid on a descending, horizontal or ascending area to reduce the vehicle speed. Ascending grade ramps can be the most effective, as gravity aids the slowing of the truck.

Local research has previously been conducted which indicates the potential for truck escape ramps and arrester beds to successfully capture errant vehicles (Nielsen 1996). Through such studies general recommendations into the determination of requirements for arrester beds, geometric factors describing their construction, and general advice as to the type of aggregate material which should be used have been developed (Austroads 2003a). To date however there are no specific nationally recognised guidelines which outline the design and installation of these facilities. Various Australian state road authorities currently have their own guidelines for the implementation of such facilities, and advocate their use be factored into the initial design of roads with steep grades, rather than as a reactive countermeasure based on the occurrence of crashes.

Due to the small proportion of crashes which are attributed to heavy vehicle brake failure, the availability of reliable data which describes the effectiveness of such facilities is extremely limited. Western Australia’s first arrester bed, situated on the Great Eastern Highway near Perth, as shown in Figure 7.9, was constructed in 1993 following a multiple fatal crash and is reported to have been used by heavy vehicles several times since.

Source: Wikipedia

Figure 7.9: Truck arrester bed (Greenmount Hill, Perth)

Ogden (1992) comments on American research studies regarding the effectiveness of six truck escape ramps, and noted that the most successful construction resulted in a 43% reduction and a benefit-cost ratio of 10:1. Also noted by the studies were crashes which occurred when truck drivers chose not to use the escape ramp, instead opting to ‘ride it out’, without success.

In summary, while truck escape ramps have proven successful in some cases, they are largely limited in applicability due to surrounding road geometry and the tendency of truck drivers not to utilise them.

Harwood et al. (2003) also mentions that some U.S. highways agencies have provided parking places at the top of particularly long and steep grades in order to provide truck drivers with an opportunity to check the temperature of their brakes before making the descent.

Additional comment on road design for trucks can be found in the Austroads report written by McLean, Tziotis and Gunatillake (2002). Included in this report is discussion on truck-based standards for:

- grades
- acceleration lanes
- horizontal curves
- vertical curves
- when to apply truck based standards for these road design elements.

8 DRAFT REVISIONS TO ROAD SAFETY AUDIT CHECKLISTS

A road safety audit is a formal examination of a future road or traffic project or an existing road, whereby an independent qualified team reports on the project's crash potential and safety performance (Austroads 2002b). An audit may be undertaken at any stage of a project, i.e. from feasibility assessment to assessment of an existing road.

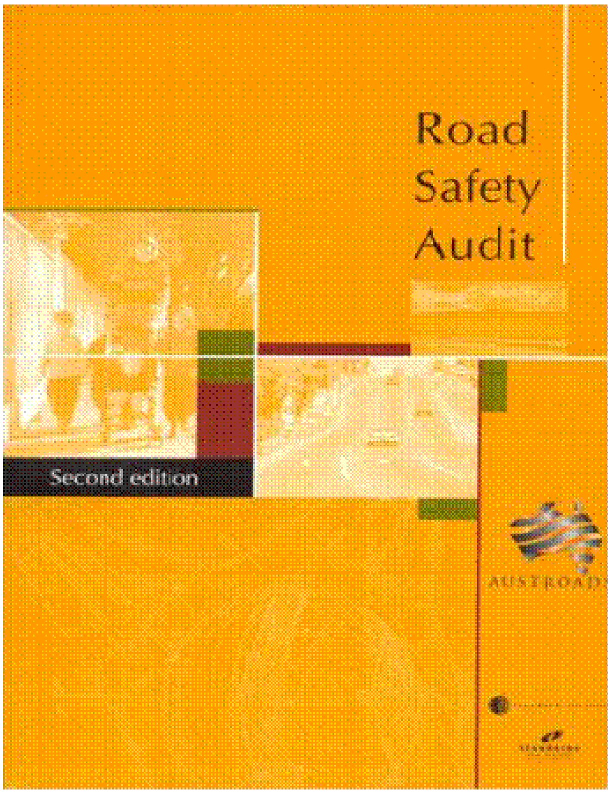


Figure 8.1: Austroads Road Safety Audit guide, 2nd Edition, 2002

Macaulay and McInerney (Austroads 2002c) estimated the benefit/cost ratio (BCR) for implementing audit recommendations at the design stage ranged from 3:1 to 242:1 and that nine in ten recommendations had a BCR greater than one. For audits of existing roads the BCR for implementing recommendations from each audit ranged from 2.4:1 to 8.4:1 and eight in ten recommendations had a BCR greater than one.

The Austroads guide for road safety auditing (Figure 8.1) provides practitioners with principles and advice on good practice in road safety auditing. These guidelines include six checklists:

- feasibility stage audit
- preliminary design stage audit
- detailed design stage audit
- pre-opening stage audit
- roadwork traffic scheme audit
- existing roads: road safety audit.

These checklists can help the road safety auditor identify any potential safety issues and include either direct or indirect reference to heavy vehicles in relation to:

- lay-bys, and parking and rest areas
- lane widths
- swept paths, turning radii
- off-street loading and unloading facilities
- visibility of intersection displays and reflective devices at different vehicle heights
- pavement surface
- drivable batter slopes
- signs – are truck adequately advised of route restrictions and are alternative routes clearly described
- overtaking opportunities
- shoulders at bends.

The current Austroads Road Safety Audit guide, published in 2002 will be reviewed and updated. It is planned that the guide will be superseded by *Part 6: Road Safety Audits*, of the Austroads *Guide to Road Safety* by mid-2008. It is proposed, as part of the review and republishing process, that the checklists that accompany the guide will be modified to ensure that road elements, as they affect heavy vehicle safety, are more thoroughly considered when audits are conducted. This stronger emphasis will have major relevance for heavy vehicle safety on key freight routes, or along roads carrying significant volumes of heavy vehicles.

8.1 Some Suggested Amendments and Additions

The stakeholder workshop and site inspections, conducted as part of this study, each provided inputs as to what might be valuable amendments to a revised Road Safety Audit guide. Some of the areas suggested for amendment and additions include:

Height clearances to structures

The current audit checklists draw the auditor's attention to a route's provision for the size of heavy vehicles, but the specific mention of vehicle height would be helpful. B-doubles and other articulated vehicles are commonplace on many routes and often require 4.6 metres of clearance.

Horizontal alignment

Provision of information on required and desirable lane widths for various heavy vehicles would enable auditors to assess a route's suitability for the types of vehicles likely to use it.

Signage

- at rest areas

  Provision of signs indicating that rest areas are suitable for large vehicles brings rest areas to the attention of heavy vehicle drivers and might increase their chance of stopping to rest.

- on grades

  Steep grades affect heavy vehicles more severely than light vehicles. Warning signs about the need for heavier braking will be helpful to heavy vehicle drivers.

- reflectivity

  The higher driving position of heavy vehicle drivers, compared with the height of their headlights, means that the retro-reflectivity of signs can be lost. The auditor should consider this aspect of sign design and perhaps suggest larger signs where they are critical to the safe passage of heavy vehicles.

Storage capacity of lanes

Auditors should check whether the length of lanes between closely spaced intersections is sufficient to accommodate long vehicles. This is particularly important where traffic signals are located in close proximity downstream of railway level crossings, creating the possibility of trucks becoming trapped on railway lines.

Acceleration and deceleration lanes

The checklist currently draws the auditor’s attention to access points at rest areas and parking areas. Trucks typically need more acceleration and stopping distance than do cars. This characteristic should be accommodated at all points where the time and distance used for acceleration and deceleration are critical, such as at freeway entrance/exit ramps, railway level crossings and signalised intersections.

Intersection signage

Auditors need to check that intersection signage, whether directional, advisory or regulatory, is large and clear enough to be visible from truck cabins.

Edge of seal drop-off

The checklist questions already mention widening of seals on bends to cater for the swept path of long vehicles, but attention should also be given to the condition of the edge of the seal along straight road sections.

Clear zones

Where barriers are installed to shield traffic from roadside hazards, it will sometimes be necessary for these barriers to be specifically designed to withstand heavy vehicle impacts. Auditors should note whether heavy vehicle barriers are provided in situations where management of errant heavy vehicles is critical.

Local Area Traffic Management (LATM)

While the larger heavy vehicles are unlikely to attempt to enter most local areas, the auditor’s attention should be drawn to the need for LATM devices to allow the passage of service vehicles, emergency vehicles and buses.

Railway level crossings

The presence of railway level crossings should be explicitly noted in audit inspections and auditors need to be aware of the requirements of heavy vehicles at such crossings. Specific areas of importance are sight distance (both for stopping and for moving off) and queuing distance downstream of the crossing.

Clearance times for signalised intersections

This may involve consideration of the need for extended yellow and all-red periods.

9 DRAFT STRATEGY FOR HEAVY VEHICLE FREIGHT ROUTES

The following activities are put forward as potentially valuable in terms of improving the safety of Australia's heavy vehicle freight routes based upon the results of this project. The strategies are divided into two categories, short term measures and long term measures. Short term measures should be undertaken within the next two to three years. Longer term measures, which will require a greater time frame are also put forward.

9.1 Short Term Measures

The following actions could be undertaken within the more immediate future:

- Amendments and additions that more strongly focus on heavy vehicles (Section 8.1) be incorporated into the revised Austroads Road Safety Audit guide (2002).
- A simplified risk assessment guideline for roadside hazard assessment, cost estimation and prioritisation which includes reference to heavy vehicles should be incorporated with the Road Safety Audit Checklists.
- The Road Safety Audit training course be expanded to reflect the greater emphasis on heavy vehicle safety in the revised Road Safety Audit guide.
- The appropriateness of sight distances associated with existing overtaking zones on major heavy vehicle freight routes be assessed.
- Road design guidelines be reviewed in terms of:
  - suitability of various service road access point designs for heavy vehicles
  - suitability of minimum required lane widths for heavy vehicles at speeds greater than 90 km/h.
- Existing work to determine the site characteristics (including minimum heavy vehicle volumes) which make various heavy vehicle specific road design features cost effective should be built on, to aid in proactive risk minimisation.
- ITS solutions to heavy vehicle crash problems (e.g. intelligent rollover warning signs, advisory speed signs on curves) should be reviewed.
- The role of road surface characteristics (e.g. texture and rutting) on heavy vehicle crash risk should be researched.
- Skid resistance criteria for heavy vehicle safety should be researched.
- The effectiveness of rest areas in promoting heavy vehicle safety should be investigated.

9.2 Longer Term Measures

The National Heavy Vehicle Safety Strategy (NTC 2002a) indicates that existing black spot and mass action programs include a range of appropriate countermeasures. This work has supported the importance of continuing to implement many of the solutions listed, including:

- clearance of roadside hazards
- shoulder sealing
- passing lanes
- programs to minimise the risk posed by utility poles.

This work has indicated that some of the other countermeasures listed require qualification and/or further investigation:

- Use of barriers to reduce the risk posed by roadside hazards. The ability of the standard barrier types to safely redirect large vehicles is questionable. Further work is required to provide guidance on what circumstances warrant the use of heavy vehicle specific barriers.
- Audible edge lining. The ability of various types and profiles to be detected by various heavy vehicle types (while not presenting a hazard to two-wheeled traffic) should be further investigated, as should alternative technologies such as systems which interact with on-board vehicle devices. Such an investigation could be considered a short term measure, however actioning the findings would be expected to be a long term measure.
- Night-time delineation. Differing driver eye heights for heavy vehicles and passenger vehicles make delineating for both groups using retro-reflective materials difficult. Investment in the development, trial (including heavy vehicle specific trials) and implementation of better retro-reflective materials, or alternatives, such as LED technology, may be warranted.

Other appropriate long term measures are:

- provide skid resistance treatments (at blackspot locations) to prevent the exacerbation of the reduced stopping and manoeuvring abilities of trucks
- provide lane widths of at least that proscribed by the relevant road design guidelines
- continue the safe systems approach. Many of the crashes considered during this study could not be linked to any road related factors. Further, ‘engineering’ treatments such as rest areas can only be effective if supported by non-engineering interventions
- review clear zone criteria to take account of heavy vehicles
- review the design of intersections on key freight routes to better and more safely accommodate heavy vehicle traffic. The key areas of review include:
  - kerb returns
  - storage length or turn lanes
  - median widths
  - visibility restrictions to opposing right lanes.
- trial selected ITS treatments specifically for heavy vehicles.

REFERENCES

AASHTO 2002, *Roadside design guide*, 3rd ed., American Association of State Highway & Transportation Officials, Washington, DC.

Armour, M, Carter, R, Cinquegrana, C & Griffith, J 1989, *Study of single vehicle rural accidents*, report GR/89/4, Road Traffic Authority, Melbourne, Victoria.

Australian Transport Safety Bureau 2004, *Heavy truck crashes at 500 to 1499 kilometers outward distance from base 1998 to 2002,* Australian Transport Safety Bureau, Canberra.

Australian Transport Safety Bureau 2005, *Road deaths Australia: 2004 Statistical summary*, Australian Transport Safety Bureau, Canberra, viewed 7 April 2006, <http://www.atsb.gov.au/publications/2004/pdf/rfa2004.pdf>.

Austroads 2002a, *Urban road design: guide to the geometric design of major urban roads*, AP-G69/02, Austroads, Sydney, NSW.

Austroads 2002b, *Road safety audit*, AP-G30/02, Austroads, Sydney, NSW.

Austroads 2002c, *Evaluation of the proposed actions emanating from road safety audits*, by J. Macaulay J & R.McInerney, AP-R209/02, Austroads, Sydney, NSW.

Austroads 2002d, *Geometric design for trucks, when where and how?* by J. McLean, M. Tziotis & T. Gunatillake, AP-R211/02, Austroads, Sydney, NSW.

Austroads 2003a, *Rural road design: guide to the geometric design of rural roads*, AP-G1/03, Austroads, Sydney, Australia.

Austroads 2003b, *Guide to traffic engineering practice: part 7, traffic signals*, AP-G11.7/03, Austroads, Sydney, NSW.

Austroads 2005a, *Guidelines for the management of road surface skid resistance*, AP-G83/05, Austroads, Sydney, NSW.

Austroads 2005b, *Guide to traffic engineering practice: part 5, intersections at grade*, AP-G11.5/05, Austroads, Sydney, NSW.

Baas, P, Charlton, S & De Jong, D 2004, *Review of lane delineation*, Transport Engineering Research New Zealand Ltd, Manukau, New Zealand.

Cairney, P 1993, ‘Current issues in delineation’, *Road and Transport Research*, vol.2, no. 2, pp. 28 – 39.

Cairney, P 1994, ‘The effect of profile line-marking on in-vehicle noise levels’, WD RS 94/001, Australian Road Research Board, Vermont South, Vic.

Cairney, P & Gunatillake, T 2001, ‘Significance of friction, texture and rutting in crashes at signalised intersections’, RC1617-1, ARRB Transport Research, Vermont South, Vic.

Cairney, P, Cusack S & Ford D 1997, ‘Evaluation of edge line audible markers’, CR RE6047, ARRB Transport Research, Vermont South, Vic.

California Department of Transportation 2001, *Evaluation of milled-in rumble strips, rolled-in rumble strips and proprietary applications*, draft report, California Department of Transportation, California.

Carnaby, B 2004, 'Road marking – high priority road safety, or just road maintenance?, *2004 Road Safety Research, Policing and Education Conference, Perth, Australia* , Road Safety Council of Western Australia, Perth.

Case, HW, Hulbert, SF & Mellinger, R 1969, *Evaluation study – safety aspects of roadside rest program,* report no. 69-69, ITTE, UCLA, Los Angeles, California.

Catchpole, J 1989, *The role of road and environment factors in fatal accidents*, ARR 172, Australian Road Research Board, Vermont South, Victoria.

Cleveland, DE, 1987, 'Effects of resurfacing on highway safety'. In *Relationship between safety and key highway features: a synthesis of prior research*, *state of the art report 6,* Transportation Research Board, Washington DC, pp. 78 -95.

Cooper DR, Jordan P & Young JC 1980, *The effect on traffic speeds of resurfacing a road*, supplementary report 571, Transportation and Road Research Laboratory, Crowthorne, Berkshire.

Corben, B, Deery, H, Mullan, N & Dyte, D 1997, *The general effectiveness of countermeasures for crashes into fixed roadside objects*, report no. 111, Monash University Accident Research Centre, Monash University, Clayton, Vic.

Douglas J 2000, 'Making the delineation message clear', *Roadmarking Industry Association of Australia and New Zealand Roadmarkers Federation Joint Conference, 6th, 2000, Canberra,* Roadmarking Industry Association of Australia, Victoria.

Elvik, R & Vaa, T (eds) 2004, *Handbook of road safety measures*. Oxford, Pegamon Press.

Figueroa Medina, A & Tarko, A 2005, 'Speed factors on two-lane rural highways in free-flow conditions', *Transportation Research Record 1912*, pp. 39-46.

Gillespie, RI 2002, 'High friction surfacing, saving lives for over 30 years', *IRF and ARF Asia Pacific Roads Conference and Exhibition, 2002, Sydney, New South Wales, Australia*, ARF, Melbourne, Vic.

Glennon, JC 1987, 'Effects of pavement/shoulder drop-offs on highway safety', In *Relationship between safety and key highway features: a synthesis of prior research, state of the art report 6*, Transportation Research Board, Washington, DC.

Hanscom, FR 1987, 'Weight specific highway sign effects on heavy trucks', *Transportation Research Record 1114*, pp. 31-36.

Harwood, DW, Pietrucha MT, Wooldridge, MD, Brydia, RE & Fitzpatrick K 1995, *Median intersection design,* NCHRP report 375, Transportation Research Board, Washington, DC

Harwood, DW, Potts, IB, Torbic DJ, & Glauz WD 2003, *CTSSP Synthesis of Safety Practice 3: Highway/Heavy Vehicle Interaction.* Transportation Research Board, Washington DC

Haworth, N & Symmons, M 2003, *Review of truck safety - stage 2: update of crash statistics*, report no. 205, Monash University Accident Research Centre, Clayton, Victoria

Haworth, N, Vulcan P, & Sweatman, P, 2002, *Truck safety benchmarking study*, National Transport Commission.

Hudson, KC & Mumm, P 2003, 'Six years of calcined bauxite', *ARRB Transport Research conference, 21st 2003, Cairns, Queensland, Australia*, ARRB Transport Research , Vermont South, Vic.

Iskander, R & Stevens, A 2005, ‘The effectiveness of high friction surfacing on crash reduction’, *International Conference on Surface Friction, Christchurch, New Zealand, 2005*, Transit New Zealand, Wellington, 18pp.

Jacques, N, Franklyn, M, Corben, B, & Candappa, N 2003, *The investigation of the performance of safety barriers in relation to heavy vehicle crashes*, R&D project 832, VicRoads, Kew, Vic.

Janson, BN, 1999, *Evaluation of downhill truck speed warning system on I-70 west of Eisenhower Tunnel*, Report for the Colorado Department of Transportation.

King GF 1989, *Evaluation of safety roadside rest areas*, National Cooperative Highway Research Program report 324, Transportation Research Board, Washington DC

King, K 1986, *Rural traffic crashes in Queensland, 1984*, report CR45, Federal Office of Road Safety, Canberra.

Kockelman K 2006, *Safety impacts and other implications of raised speed limits on high-speed roads*, NCHRP Research Results Digest 303, viewed on May 14 2007, <http://www.trb.org/publications/nchrp/nchrp_rrd_303.pdf >.

Lennie, C & Bunker, JM 2005, ‘Using lateral position information as a measure of driver behaviour around MCVs’, *Road & Transport Research,* vol.14, no.3, pp. 62-77.

LTSA, 1995, *Shoulder improvements,* Land Transport Safety Authority, Wellington, New Zealand.

McLean, J 2001, ‘Study on cross sections for national highways’, contract report to Commonwealth Department of Transport and Regional Services’, RC91287, ARRB Transport Research, Vermont South, Vic.

McLean, J 2002, ‘Cost effective improvements to roads used by trucks’, *National Heavy Vehicle Safety Seminar, 2002, Melbourne, Victoria*, National Road Transport Commission, Melbourne.

National Transport Commission 2002a, *Publications - National heavy vehicle safety strategy*, Melbourne, Vic, viewed 5 April 2006, <http://www.ntc.gov.au/DocList.aspx?page=A02400005500000320>.

National Transport Commission 2002b, *Summary Report: National heavy vehicle safety seminar*, 22 & 23 October, 2002, Melbourne, Vic viewed 5 April 2006, <http://www.ntc.gov.au/filemedia/Publications/SummaryReport.pdf>.

National Transport Commission 2002c, *Performance characteristics of the Australian heavy vehicle fleet,* viewed 30th March 2007, *<http://www.ntc.gov.au/filemedia/Reports/PerformanceCharacteristicstheAus.doc>.*

National Transport Commission 2005, *National guidelines for the provision of rest areas and facilities: final report*, NTC, Melbourne, Vic.

Nielsen, WA 1996, ‘Arrester beds for heavy combination vehicles’, *Combined 18th ARRB Transport Research Conference and Transit New Zealand Land Transport Symposium, 1996, Christchurch, New Zealand*, vol.18, no.4, ARRB Transport Research, Vermont South, Vic., pp.355-370.

Ogden, K 1992, *Benefit cost analysis of road trauma countermeasures: rural road and traffic engineering programs*, report 34, Monash University Accident Research Centre (MUARC), Clayton, Vic.

Ogden, K 1995, *The safety benefits of sealing the shoulders of rural roads*, Civil Engineering Working Paper CEWP 95/T1, Monash University, Clayton, Vic.

Parfitt, C & Lewando, J 2005, Does friction and colour equal safety?', *International Conference on Surface Friction, Christchurch, New Zealand, 2005*, Transit New Zealand, Wellington, 11pp.

Prem, H, Ramsay, E, Fletcher, C, George, R & Gleeson, B 1999, *Estimation of lane width requirements for heavy vehicles on straight paths*, ARR 342, ARRB Transport Research Ltd, Vermont South, Vic.

Sinhal, R 2005, 'The implementation of a skid policy to provide the required friction demand on the main road network in the United Kingdom', *International Conference on Surface Friction, Christchurch, New Zealand, 2005*, Transit New Zealand, Wellington, 13pp.

Sivak M, Flannagan, M & Gellatly AW 1993, 'Influence of truck driver eye position on effectiveness of retroreflective traffic signs', *Lighting Research and Technology*, vol.25, no.1, pp. 31 – 36.

Standards Australia 1994, *Manual of uniform traffic control Devices Part 2: Traffic control devices for general use*, AS 1742.2—1994, Standards Australia, North Sydney.

Standards Australia 1999, *Road safety barrier systems*, AS/NZS 3845:1999, Standards Australia, North Sydney.

Sweatman, PF, Ogden, KJ, Haworth, N, Vulcan, AP & Pearson, RA (1990) *NSW heavy vehicle crash study final technical report*, CR92, Federal Office of Road Safety, Canberra, & CR5/90, Roads and Traffic Authority, Sydney, NSW.

Tan, H, Cairney, P, McLean, J & George, R 1996, 'Guidelines on road environment for road transport vehicles', contract report to the Roads and Traffic Authority of NSW, CR OC4816, ARRB Transport Research, Vermont South, Vic.

Taylor, WC, Sung, N, Kolody, KA & Jawad, A, 1999, *A Study of Highway Rest Area Characteristics and Fatigue Related Truck Crashes*, Michigan Department of Transportation, Lansing, MI.

Torpey, S, Ogden, K, Cameron, M & Vulcan, P 1991, *Indicative benefit/cost analysis of road trauma countermeasures*, Monash University Accident Research Centre, Clayton, Vic.

Troutbeck, R 1981, *Overtaking behaviour on Australian two-lane rural highways*, special report 20, Australian Road Research Board, Vermont South, Vic.

VicRoads 2005, *Accepted safety barrier products*, Road design note – RDN 9-12a, viewed 12th April 2007, <http://www.vicroads.vic.gov.au/Home/RulesStandardsRegulations/RoadAndTrafficDesignStandards/RoadDesignNotes.htm>.

Williamson, A, Feyer, A, Friswell, R & Sadural, S 2000, *Driver fatigue: A survey of professional long distance heavy vehicle drivers in Australia*, discussion paper, National Road Transport Commission, Melbourne, Vic.

APPENDIX A SITES INSPECTED

Victoria

Road Name	Location
Goulburn Valley Hwy	At Murray Valley Hwy and Benalla-Tocumwal Rd, Cobram (rural)
Goulburn Valley Hwy	7.94 km N Cobram-Koonoomoo Rd, south of Tocumwal (rural)
Goulburn Valley Hwy	2.27 km S of A300, Shepparton (rural)
Goulburn Valley Hwy	1.32 km S of Shepparton Alt. Route, Shepparton (rural)
Goulburn Valley Hwy	At Seymour-Tooborac Rd, Seymour (rural)
Hume Hwy	7.27 km N of Great Alpine Road, Wangaratta (rural)
Hume Hwy	1.08 km N Glenrowan-Myrtleford Rd, Glenrowan (rural)
Hume Hwy	At Mahoneys Rd / Camp Rd, Fawkner (urban)
Hume Hwy	50 m N of Anderson Rd, Fawkner (urban)
Hume Hwy	At Cooper St , Epping(urban)
Hume Hwy	150 m N of Rushwood Rd, Craigieburn (urban)
Hume Hwy	At Donnybrook Rd, KalKallo (urban)
Kings Way	150 m S of Flinders St, Melbourne (urban)
Princes Hwy East	2.37 km W of Sth Gippsland Hwy, Sale (rural)
Princes Hwy East	410 m E of Sale-Heyfield Road, Fulham (rural)
Princes Hwy East	1.54 km W of Hyland Hwy, Traralgon (rural)
Princes Hwy East	At Thewlis Rd → Michael St, Pakenham (urban)
Princes Hwy East	840 m E of Wellington Rd, Clayton (urban)
Princes Hwy West	At Droop St, Footscray (urban)
Princes Hwy West	At Little Boundary Rd, Laverton (urban)
Princes Hwy West	At Kororoit Creek Rd, Altona (urban)
Princes Hwy West	180 m S of Railway Av, Altona Meadows (urban)

New South Wales

Road Name	Location
Cumberland Hwy	At Dartford Rd, Normanhurst (urban)
Cumberland Hwy	87 m W of Boundary Rd, Pennant Hills (urban)
Cumberland Hwy	At Darcy Rd, Wentworthville (urban)
Cumberland Hwy	220 m E of Old Windsor Rd, Northmead (urban)
Cumberland Hwy	At Cabramatta Rd West, Cabramatta (urban)
Hume Hwy	100 m S of Memorial Ave, Liverpool (urban)
Hume Hwy	300 m E of Lansdowne Rd, Lansvale (urban)
Hume Hwy	At Governor Macquarie Dr, Warwick Farm (urban)
Hume Hwy	At West St, Gundagai (rural)
Hume Hwy	465 m E of Old Hume Hiwy, Welby (rural)
Hume Hwy	4.74 km E of Old Hume Hwy, Towrang (rural)
Hume Hwy	2.02 km Wt of Sloane St, Welby (rural)
Hume Hwy	1.99 km S of Sheahan Dr, Gundagai (rural)
Pacific Hwy	1.66 km S of Boundary St, Lindfield (urban)
Pacific Hwy	At Tomago Rd, Raymond Terrace (rural)
Pacific Hwy	At Kanangra Drive, Crangan Bay (rural)
Pacific Hwy	At The Lakes Way, Bulahdelah (rural)
Pacific Hwy	9.72 km N of Princes St , Cundletown (rural)
Pacific Hwy	2.82 km E of Princes St, Cundletown (rural)
Pacific Hwy	8.98 km E of The Bucketts Way, Karuah (rural)
Pacific Hwy	17.93 km E of The Bucketts Way, Katuah (rural)
Pacific Hwy	2.28 km S of Bolong Rd, Bombaderry (rural)
Princes Hwy	At Canal Rd, St Peters (urban)
Princes Hwy	33 m S of Campbell Rd, St Peters (urban)
Princes Hwy	1.66 km N of Jamberoo Rd, Oak Flats (rural)
Princes Hwy	At Strongs Rd, Tomarong (rural)
Princes Hwy	At Gipps St, Kiama (rural)

Queensland

Road Name	Location
Bruce Hwy	Pine Rivers Bridge, Griffin-Mango Hill (urban)
Bruce Hwy	At Isis Hwy, Childers (rural)
Bruce Hwy	At Capricorn Hwy, Rockhampton (urban)
Bruce Hwy	1 km E of Pamona Connection Rd, Noosa (rural)
Bruce Hwy	500 m N of Mungar Rd, Tiaro (rural)
Bruce Hwy	570 m W of Gladstone-Mt Larcom Rd, Ambrose (rural)
Bruce Hwy	2.51 km S of Rockhampton-Yeppoon Rd, North Rockhampton (rural)
Cunningham Hwy	7.7 km W of Lake Moogerah Rd, Boonah Shire (rural)
Gateway Mwy Ramp	At Fison Ave West, Pinkenba-Eagle Farm (urban)
Gateway Arterial Rd Ramp	At Links Ave North, Pinkenba-Eagle Farm (urban)
Gateway Arterial Rd Ramp	At East West Arterial Rd, Hendra (urban)
Gateway Arterial Rd	50 m N of Wynumm Rd, Murrari (urban)
Gateway Arterial Rd	500 m S of Nudgee Rd exit, Nudgee (urban)
Gateway Arterial Rd	150 m N of the Bicentennial Rd, Boondall (urban)
Ipswich Mwy	1 km W of Logan Mwy, Goodna (urban)
Ipswich Mwy	1.65 km W of West Queen St Service Rd, Redbank (urban)
Ipswich Mwy	At Centenary Hwy, Darra-Sumner (urban)
Ipswich Rd	At Venner Rd, Annerly (urban)
Ipswich Rd	At Annerly Rd, Annerly (urban)
Ipswich Rd Service Rd	At Medway St , Rocklea (urban)
Pacific Hwy	700 m S of Logan Mwy, Beenleigh (urban)

Western Australia

Road Name	Location
Albany Hwy	At Ewing St, Bentley (urban)
Albany Hwy	At Nicholson Rd, Beckenham (urban)
Albany Hwy	50 m E of Mitchell St, Canning (urban)
Albany Hwy	40 m N of Rundle St, Armadale (urban)
Albany Hwy	Wandering slk 79.4 (rural)
Albany Hwy	Boddington slk 91.9 (rural)
Albany Hwy	Boddington slk 98.2 (rural)
Albany Hwy	Boddington slk 99.6 (rural)
Albany Hwy	Boddington slk 103.5 (rural)
Albany Hwy	Williams 174.1 (rural)
Albany Hwy	Williams 176.2 (rural)
Albany Hwy	Williams 180.9 (rural)
Albany Hwy	Kojonup slk 253.7 (rural)
Albany Hwy	Kojonup slk 256.1 (rural)
Leach Hwy	At Welshpool Rd, Welshpool (urban)
Leach Hwy	At Bungaree Rd, Wilson (urban)
Leach Hwy	At Karel Ave, Rossmoyne (urban)
Leach Hwy	At Barbican St West, Shelley (urban)
Leach Hwy	30 m E of North Lake Rd, Melville (urban)
Leach Hwy	40 m E of Bull Creek Dr, Canning (urban)
Leach Hwy	140 m E of Tudor Ave, Canning (urban)

APPENDIX B SITE INSPECTION CHECKLIST

CRASH CONTRIBUTING FACTORS AND SAFETY CHECK

ROAD NAME:……………………………………………………………………………………...

LOCATION:………………………………………………………………………………………...

Crash Contributing Factors (Y/N) **Potential Crash Factors (Y/N)**

1.0 ALIGNMENT

1.1 Sight distance is poor

a) at the intersection………………………………………………………………………

b) at other points of access (e.g. property access)……………………………………

c) for overtaking (ie. vertical / horizontal alignment)…………………………………...

Comment..…………………………………………………………………………………………
……………………………………………………………………………………………………

1.2 Confusing alignment

a) of roadway (ie. new roadway)…………………………………………………………...

b) old pavement markings not removed…………………………………………………....

c) vertical – due to undulations……………………………………………………………….

Comment……………………………………………………………………………………………
……………………………………………………………………………………………………

1.3 Unsatisfactory transition from old alignment to new…………………………………….

Comment……………………………………………………………………………………………
……………………………………………………………………………………………………

1.4 Unexpected change in alignment ……………………………………………………...

Comment……………………………………………………………………………………………
……………………………………………………………………………………………………

1.5 Glare due to

a) oncoming headlights…………………………………………………………………......

b) the sun………………………………………………………………………………………..

c) 2-way service road…………………………………………………………………………..

Comment……………………………………………………………………………………………..
……………………………………………………………………………………………………...

2.0 SIGNING AND DELINEATION

2.1 Ambiguous / unclear

a) directional signing……………………………………………………………………...

b) advisory speed / warning signs…………………………………………………………

Comment……………………………………………………………………………………………

2.2 Unnecessary signing……………………………………………………………………..

Comment……………………………………………………………………………………………

2.3 Insufficient signing………………………………………………………………………….

Comment……………………………………………………………………………………………

2.4 Sign hidden or inconspicuous…………………………………………………………….

Comment……………………………………………………………………………………………

Crash Contributing Factors (Y/N) **Potential Crash Factors (Y/N)**

2.5 Sign restricts sight distance……………………………………………………………………….

Comment…………………………………………………………………………………………………...

2.6 Sign mounted at an inappropriate height………………………………………………………..

Comment………………………………………………………………………………………………….

2.7 Incorrect sign size…………………………………………………………………………………

Comment………………………………………………………………………………………………….

2.8 Insufficient or poorly spaced guide posts………………………………………………………….

Comment………………………………………………………………………………………………….

2.9 Poor curve delineation……………………………………………………………………………

Comment………………………………………………………………………………………………….

2.10 Edgelines

a) poorly maintained……………………………………………………………………………...
b) not provided…………………………………………………………………………………….

Comment………………………………………………………………………………………………….

2.11 Centreline

a) poorly maintained……………………………………………………………………………...
b) not provided…………………………………………………………………………………….

Comment………………………………………………………………………………………………….

2.12 Raised Reflective Pavement Markers (RRPM's)

a) poorly maintained……………………………………………………………………………...
b) not provided…………………………………………………………………………………….
c) insufficient………………………………………………………………………………………….

Comment………………………………………………………………………………………………….

2.13 Other Linemarkings (eg. turn arrows)

a) not provided…………………………………………………………………………………….
b) insufficient……………………………………………………………………………………….
a) poorly maintained……………………………………………………………………………...

Comment………………………………………………………………………………………………….

2.14 Unclear vehicle path through intersection or road segment…………………………………

Comment………………………………………………………………………………………………….

2.15 Traffic islands

a) not provided…………………………………………………………………………………….
b) poorly located…………………………………………………………………………………..
c) poorly delineated……………………………………………………………………………….
d) not mountable…………………………………………………………………………………..

Comment………………………………………………………………………………………………….

2.16 Speed limits

a) insufficient speed limit signs (ie. repeater)……………………………………………………
b) wrong size speed limit signs/poorly positioned………………………………………………
d) inappropriate speed limit………………………………………………………………………….

Comment………………………………………………………………………………………………….

Crash Contributing Factors (Y/N) **Potential Crash Factors (Y/N)**

5.5 Road surface unsafe for cyclist………………………………………………………………

Comment.……………………………………………………………………………………………

5.6 Bus stop/s poorly

a) located……………………………………………………………………………………..

b) designed (specify)………………………………………………………………………..

Comment……………………………………………………………………………………………

6.0 TRAFFIC SIGNALS

6.1 Traffic signals are

a) obscured by queued vehicles…………………………………………………………………..

b) obscured by poles, trees, signs, etc…………………………………………………………

c) effected by the sun rising / setting……………………………………………………………

Comment…………………………………………………………………………………………...

6.2 Traffic signal layout is poor………………………………………………………………..

Comment……………………………………………………………………………………………

……………………………………………………………………………………………………

6.3 Traffic signal phasing is unsatisfactory………………………………………………..

Comment……………………………………………………………………………………………

……………………………………………………………………………………………………

7.0 PARKING AND ACCESS

7.1 Inadequate parking facilities (specify)……………………………………………………

Comment……………………………………………………………………………………………

7.2 Unsatisfactory re-entry to the carriageway

a) service road………………………………………………..

b) private driveway………………………………………………………………………......

c) public facility (e.g. shopping centre, school grounds)…………………………………………

Comment……………………………………………………………………………………………

……………………………………………………………………………………………………

8.0 STREET LIGHTING

a) not provided…………………………………………………………………………….....

b) not satisfactory / low level………………………………………………………………………..

Comment……………………………………………………………………………………………

9.0 ROAD PAVEMENT

a) too narrow……………………………………………………………………………………

b) poorly maintained……………………………………………………………………………

c) poorly drained…………………………………………………………………………......

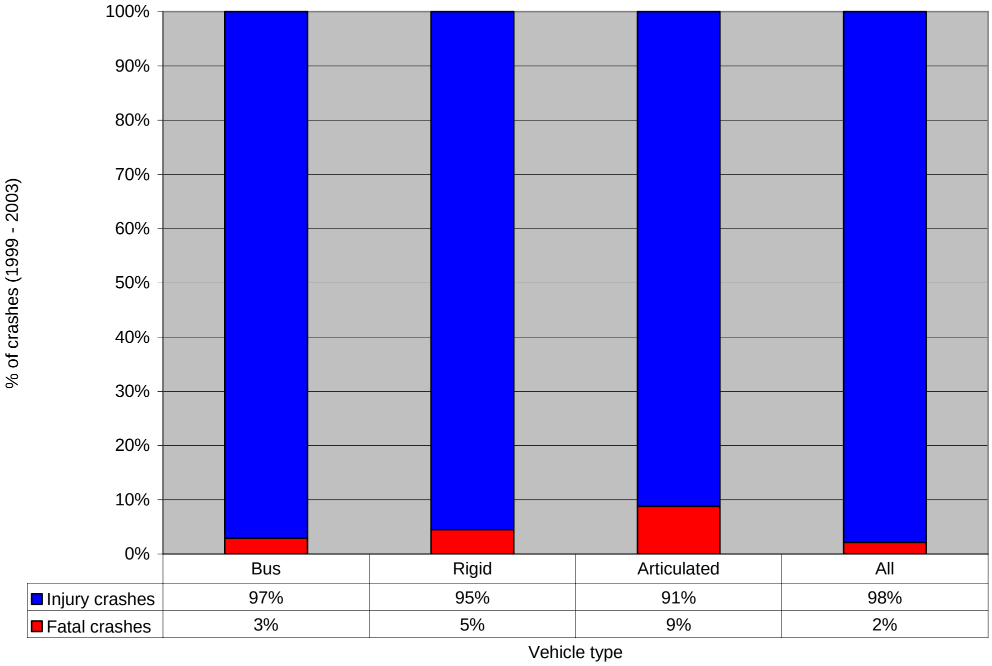
Comment……………………………………………………………………………………………

……………………………………………………………………………………………………

APPENDIX C CRASH DATA ANALYSIS

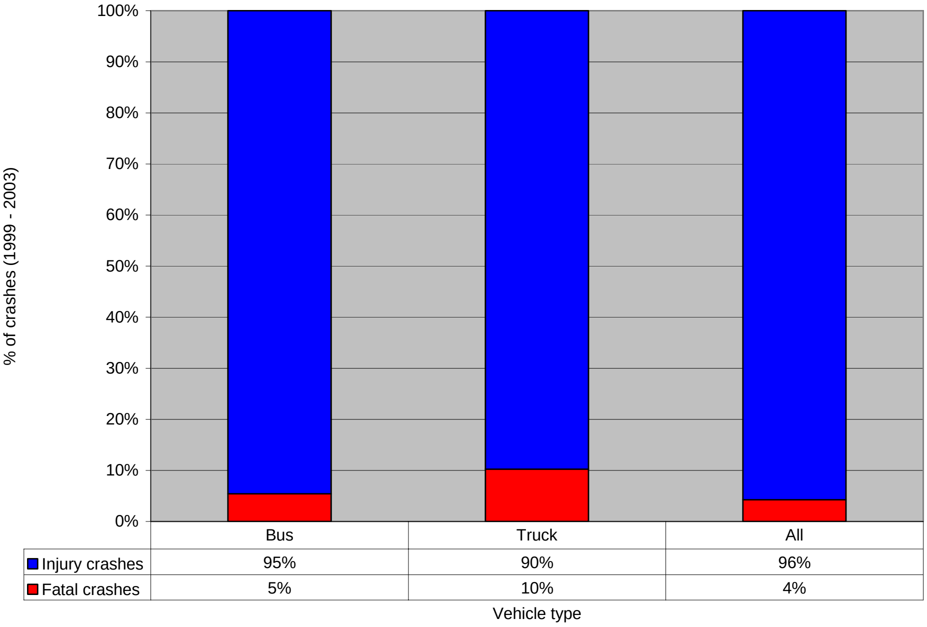
This appendix presents the results of the state road authority crash data analysis that were not presented in the body of the report:

For both Australia and New Zealand, heavy vehicle crashes are more likely to result in a fatality than are ‘all crashes’ (Figure C 1 and Figure C 2). Articulated truck crashes are more likely to result in a fatality than rigid truck or bus crashes.



	Bus	Rigid	Articulated	All
🟦 Injury crashes	97%	95%	91%	98%
🟥 Fatal crashes	3%	5%	9%	2%

Figure C 1: Crash severity by vehicle type (Australia)



	Bus	Truck	All
🟦 Injury crashes	95%	90%	96%
🟥 Fatal crashes	5%	10%	4%

Figure C 2: Crash severity by vehicle type (New Zealand)

Figure C 3 and Figure C 4 show evidence of peaks in rigid truck and bus crashes during peak commute times (8am to 9am and 4pm to 6pm). The morning and afternoon peaks for bus crashes are more pronounced than those for rigid trucks and for all crashes, which probably reflects the fact that a major role for buses (perhaps even more so than privately owned light vehicles) is commuter transport.

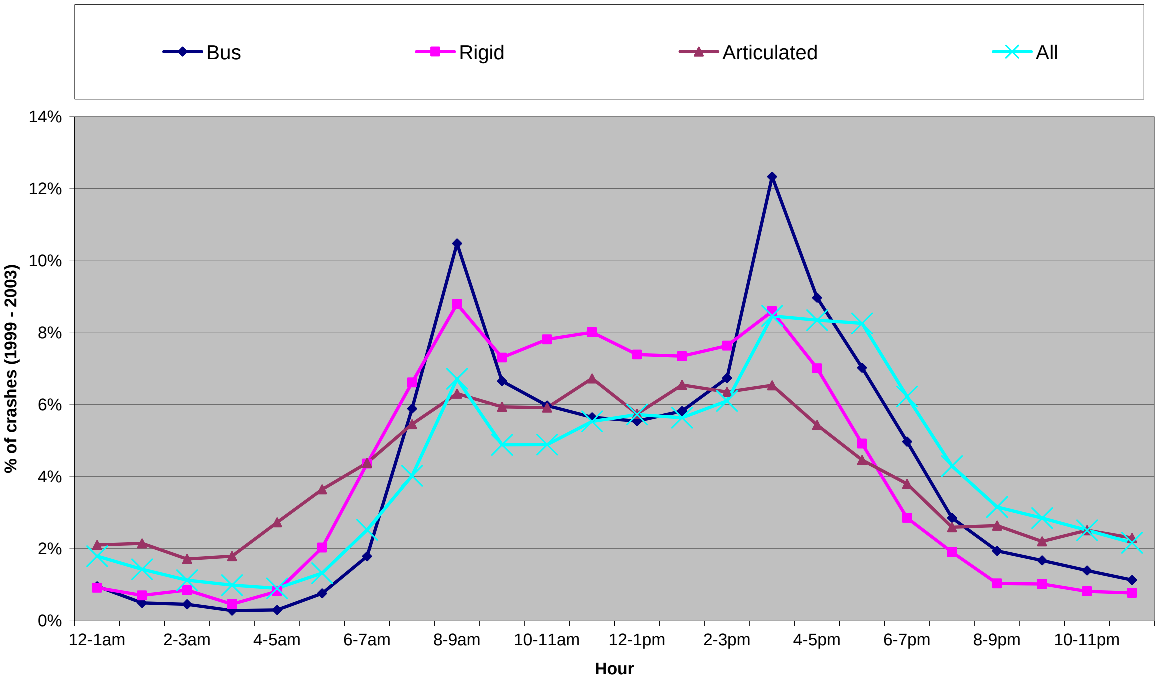


Figure C 3: Crashes by time of day (Australia)

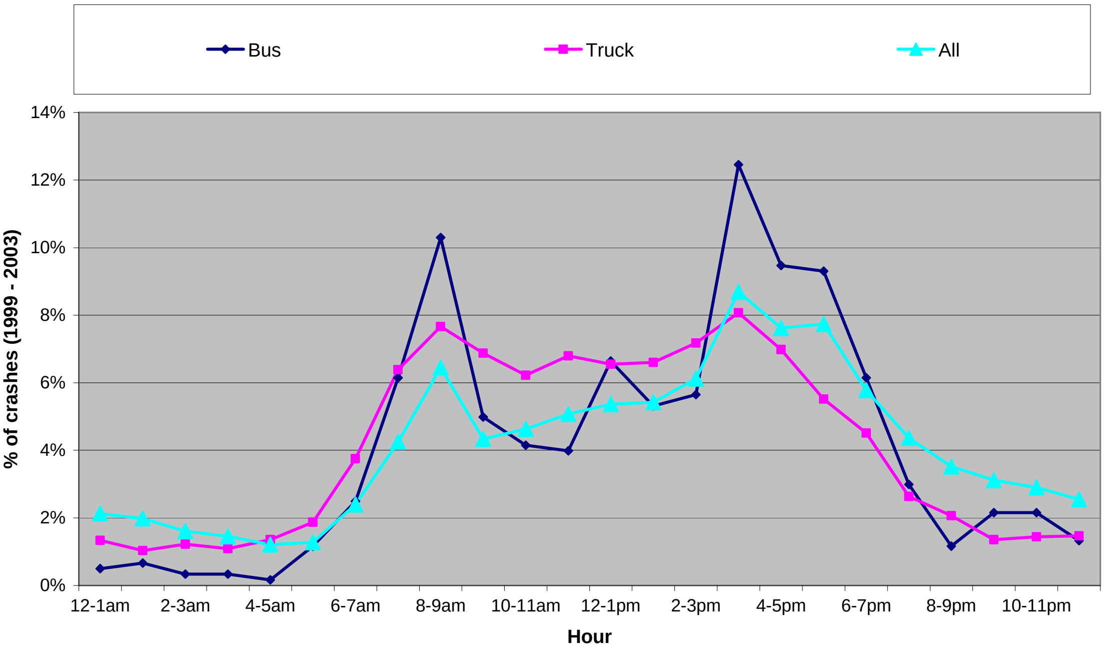
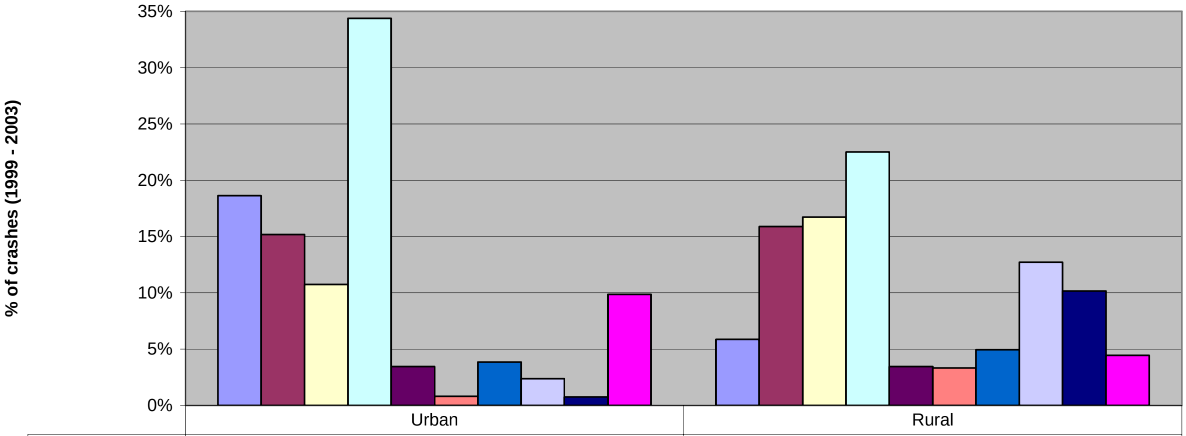


Figure C 4: Heavy vehicle crashes by time of day (New Zealand)

Figure C 5 though to Figure C 7 show that in Australia the majority of urban crashes involving all three types of heavy vehicle involve a collision with a vehicle that was travelling in the same direction. This includes rear-end and lane change crashes. In rural areas, off-path crashes are more predominant than same direction collisions for articulated trucks and also for rigid trucks, but by a smaller margin.

For buses, other major crash types in both urban and rural environments include adjacent and head-on. Out of control (or off-path) crashes were also predominant in rural road environments while pedestrian crashes accounted for 19% of urban bus crashes.



	Urban	Rural
Ped.	19%	6%
Adjacent	15%	16%
Opposite	11%	17%
Same	34%	23%
Manoevring	3%	3%
Overtaking	1%	3%
On path	4%	5%
Off path -straight	2%	13%
Off path - curve	1%	10%
Misc.	10%	4%

Urbanisation

Figure C 5: Crashes by crash type and urbanisation – buses (Australia[9])

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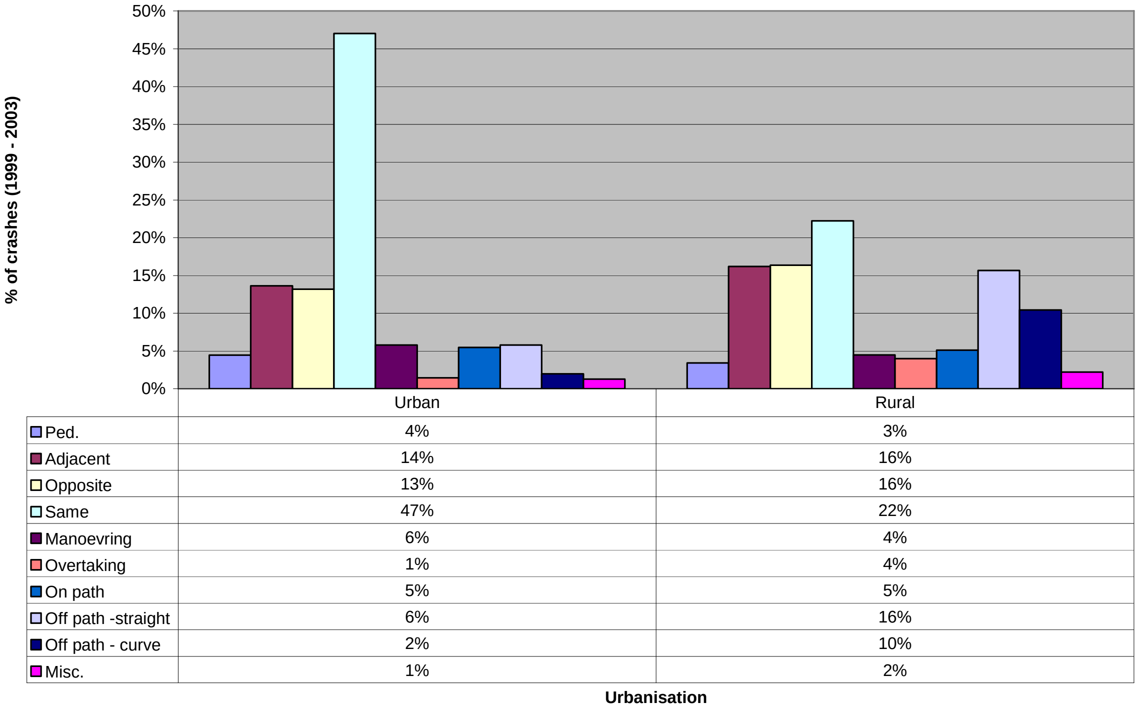
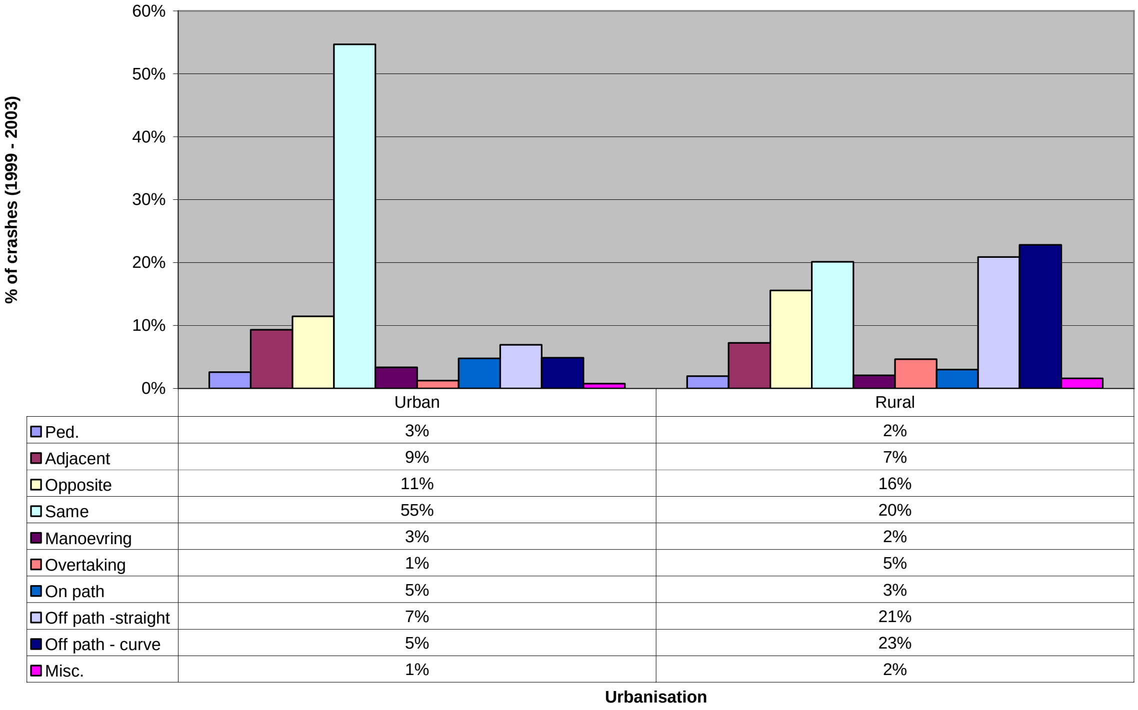
[9] Tasmanian and South Australian data is not included as these jurisdiction's systems for categorising crash types are not reconcilable with those employed by the other jurisdictions.



	Urban	Rural
■ Ped.	4%	3%
■ Adjacent	14%	16%
□ Opposite	13%	16%
□ Same	47%	22%
■ Manoevring	6%	4%
■ Overtaking	1%	4%
■ On path	5%	5%
□ Off path -straight	6%	16%
■ Off path - curve	2%	10%
■ Misc.	1%	2%

Figure C 6: Crashes by crash type and urbanisation – rigid trucks (Australia[10])



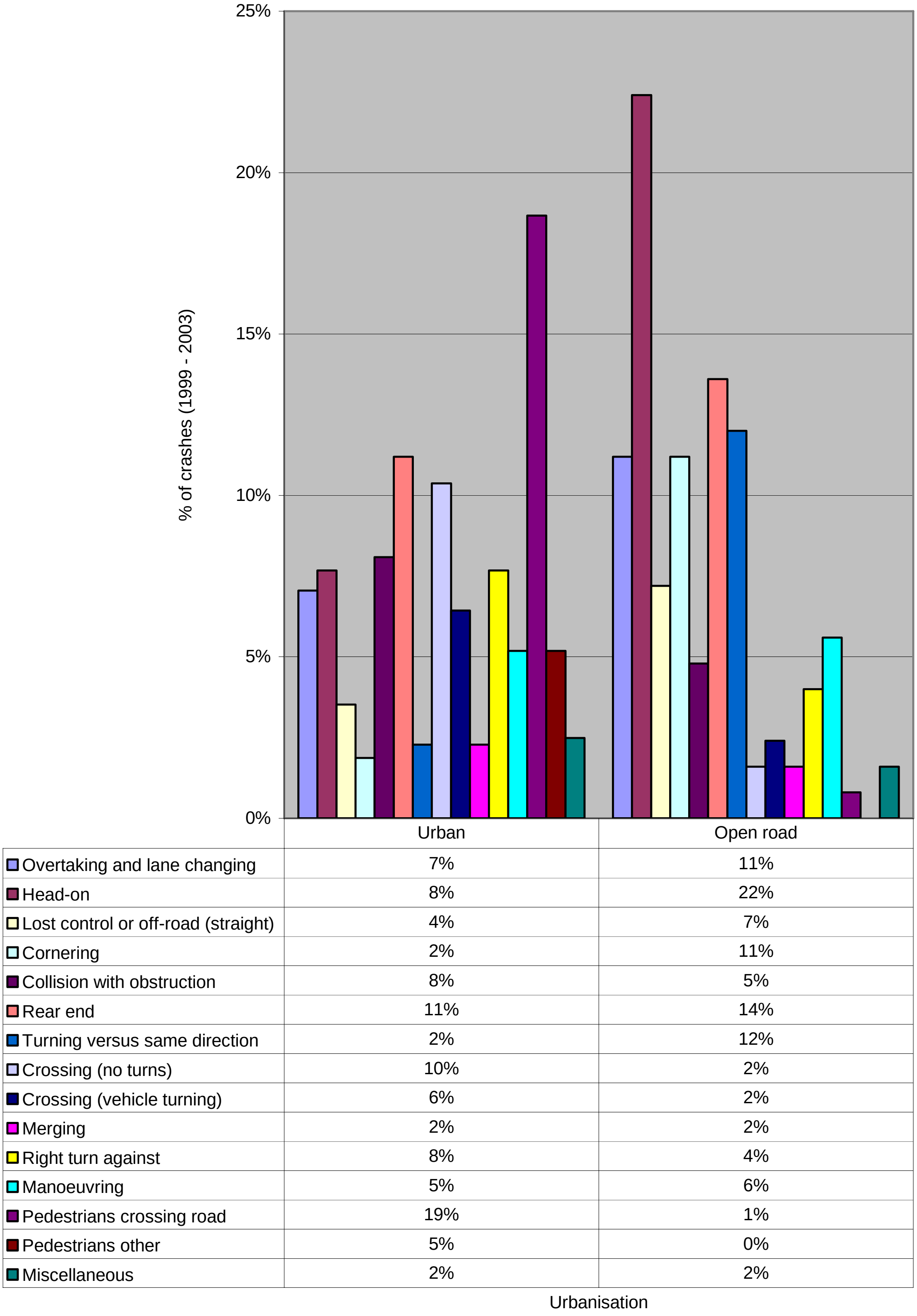
	Urban	Rural
■ Ped.	3%	2%
■ Adjacent	9%	7%
□ Opposite	11%	16%
□ Same	55%	20%
■ Manoevring	3%	2%
■ Overtaking	1%	5%
■ On path	5%	3%
□ Off path -straight	7%	21%
■ Off path - curve	5%	23%
■ Misc.	1%	2%

Figure C 7: Crashes by crash type and urbanisation – articulated trucks (Australia[10])

---

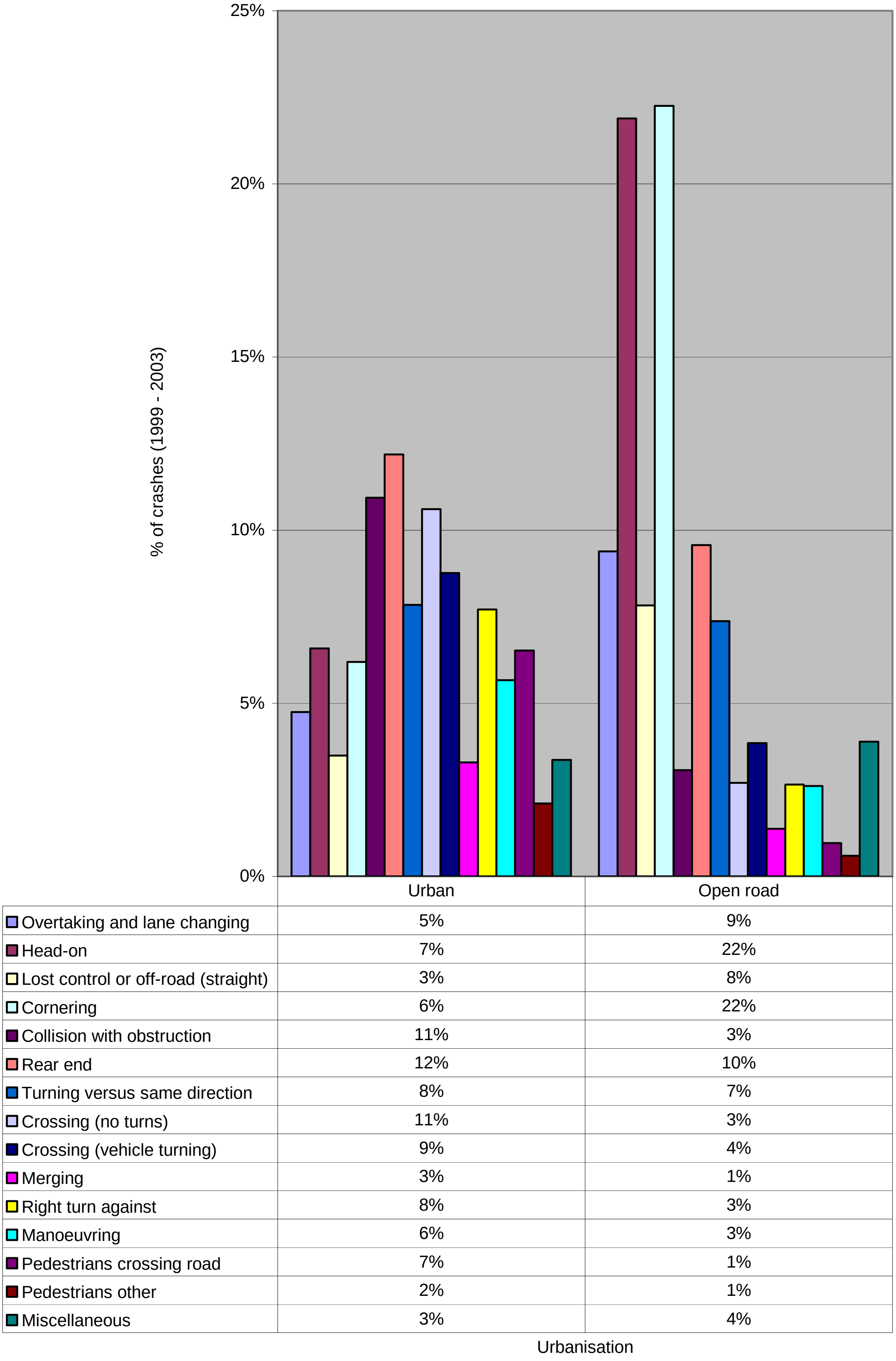
[10] Tasmanian and South Australian data is not included as these jurisdiction's systems for categorising crash types are not reconcilable with those employed by the other jurisdictions.

In New Zealand off-path and head-on collisions predominate among rural bus and truck crashes. In urban New Zealand environments pedestrian crashes represent almost one-quarter of bus crashes, while no one DCA group predominates among truck crashes (Figure C 8 and Figure C 9).



	Urban	Open road
▨ Overtaking and lane changing	7%	11%
▨ Head-on	8%	22%
☐ Lost control or off-road (straight)	4%	7%
☐ Cornering	2%	11%
■ Collision with obstruction	8%	5%
▨ Rear end	11%	14%
■ Turning versus same direction	2%	12%
☐ Crossing (no turns)	10%	2%
■ Crossing (vehicle turning)	6%	2%
■ Merging	2%	2%
🟨 Right turn against	8%	4%
■ Manoeuvring	5%	6%
■ Pedestrians crossing road	19%	1%
■ Pedestrians other	5%	0%
■ Miscellaneous	2%	2%

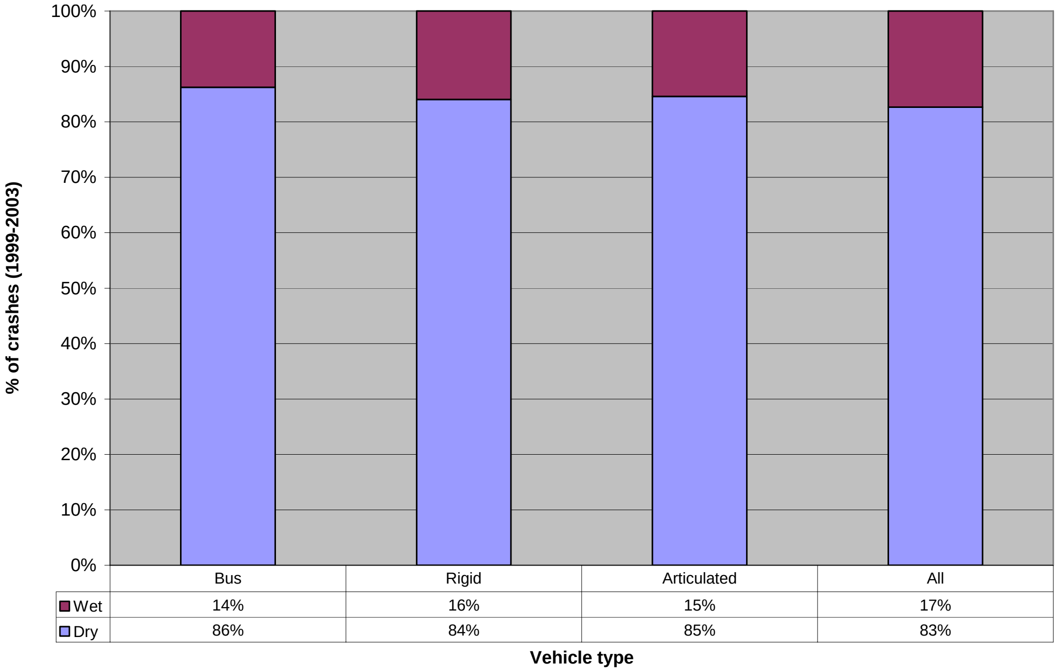
Figure C 8: Crashes by crash type and urbanisation – buses (New Zealand)



	Urban	Open road
Overtaking and lane changing	5%	9%
Head-on	7%	22%
Lost control or off-road (straight)	3%	8%
Cornering	6%	22%
Collision with obstruction	11%	3%
Rear end	12%	10%
Turning versus same direction	8%	7%
Crossing (no turns)	11%	3%
Crossing (vehicle turning)	9%	4%
Merging	3%	1%
Right turn against	8%	3%
Manoeuvring	6%	3%
Pedestrians crossing road	7%	1%
Pedestrians other	2%	1%
Miscellaneous	3%	4%

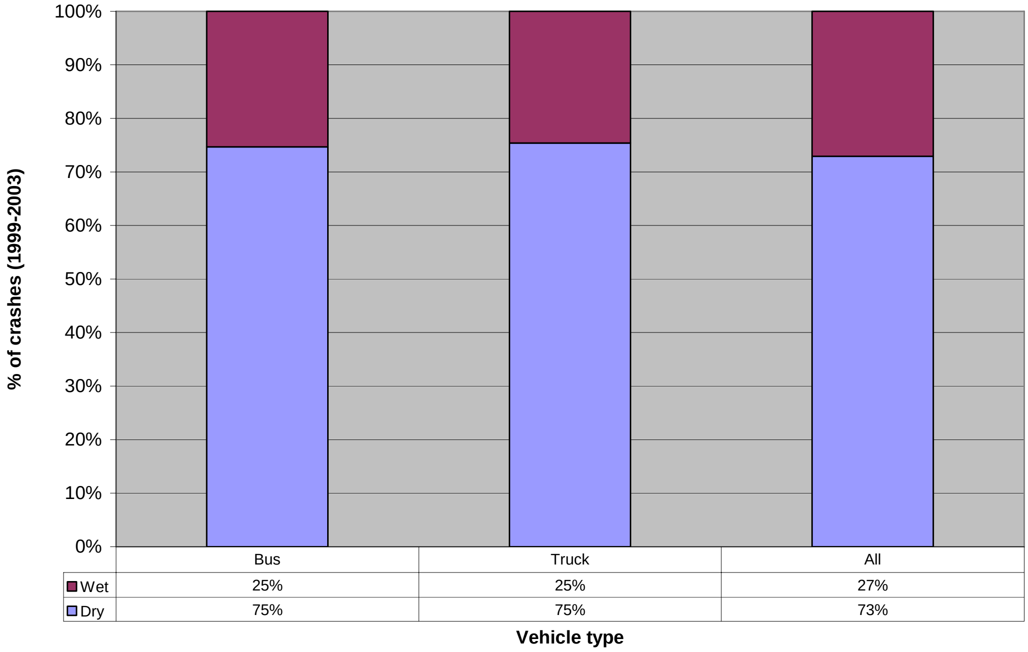
Figure C 9: Crashes by crash type and urbanisation – trucks (New Zealand)

Figure C 10 and Figure C 11 suggest that for both Australia and New Zealand, the proportion of heavy vehicle crashes that occur on a wet road surface is no greater than the proportion of 'all' crashes that occur on a wet road surface.



	Bus	Rigid	Articulated	All
▨ Wet	14%	16%	15%	17%
▨ Dry	86%	84%	85%	83%

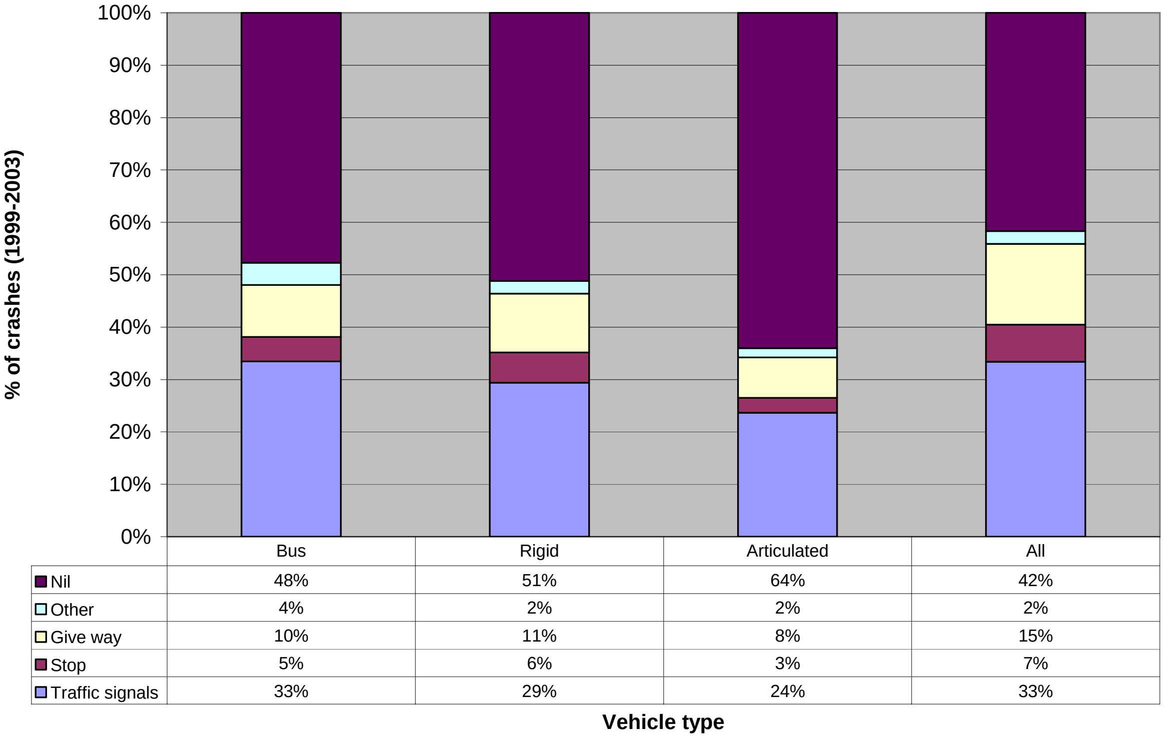
Figure C 10: Crashes by road surface condition (Australia)



	Bus	Truck	All
▨ Wet	25%	25%	27%
▨ Dry	75%	75%	73%

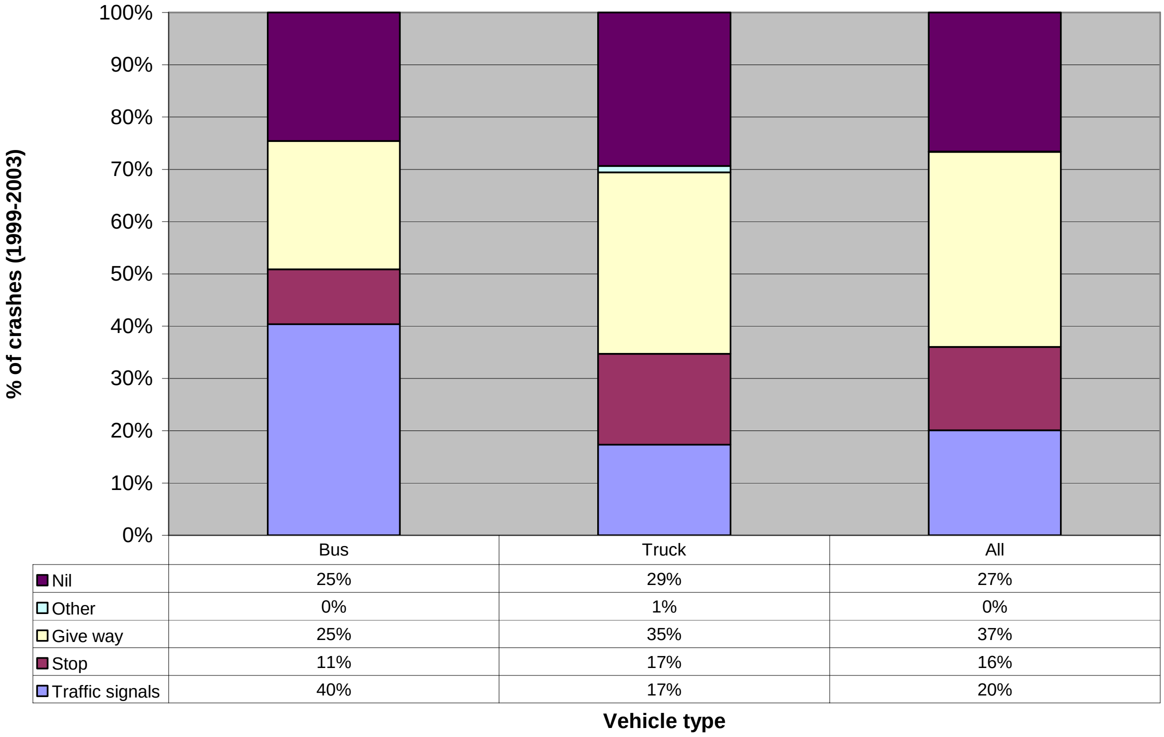
Figure C 11: Crashes by road surface condition (New Zealand)

Figure C 12 shows that of the crashes which occurred at intersections in Australia, most occurred where there were no traffic controls or at traffic signals. This was true for all heavy vehicle types. In New Zealand, most heavy vehicle crashes occurred where there were no traffic control or at a give way sign (Figure C 13).



	Bus	Rigid	Articulated	All
■ Nil	48%	51%	64%	42%
□ Other	4%	2%	2%	2%
□ Give way	10%	11%	8%	15%
■ Stop	5%	6%	3%	7%
■ Traffic signals	33%	29%	24%	33%

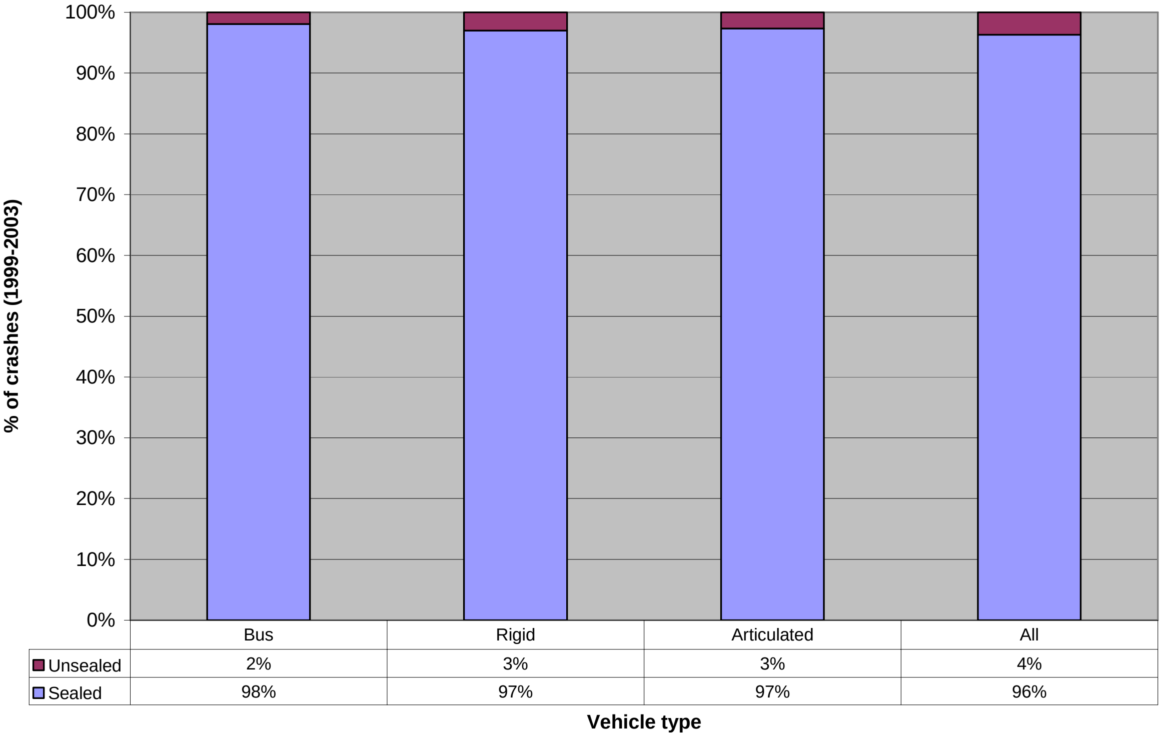
Figure C 12: Crashes by traffic control (Australia)



	Bus	Truck	All
■ Nil	25%	29%	27%
□ Other	0%	1%	0%
□ Give way	25%	35%	37%
■ Stop	11%	17%	16%
■ Traffic signals	40%	17%	20%

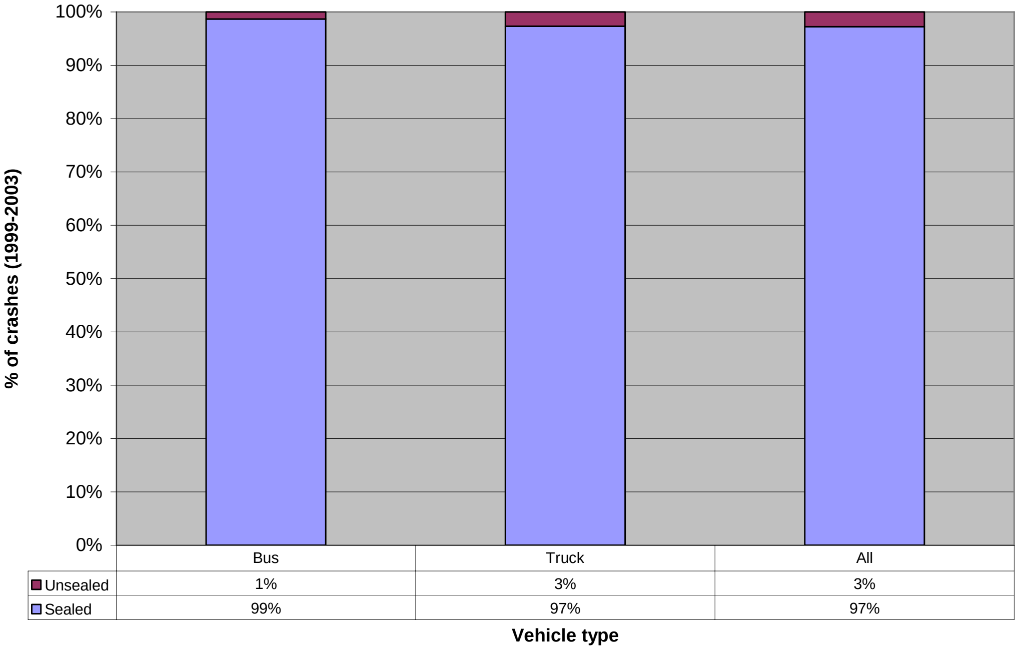
Figure C 13: Crashes by traffic control (New Zealand)

The vast majority of heavy vehicle crashes in Australia and New Zealand occurred on sealed road (Figure C 14 and Figure C 15).



	Bus	Rigid	Articulated	All
Unsealed	2%	3%	3%	4%
Sealed	98%	97%	97%	96%

Figure C 14: Crashes by road surface type (Australia)



	Bus	Truck	All
Unsealed	1%	3%	3%
Sealed	99%	97%	97%

Figure C 15: Crashes by road surface type (New Zealand)

APPENDIX D SITE INSPECTION FINDINGS

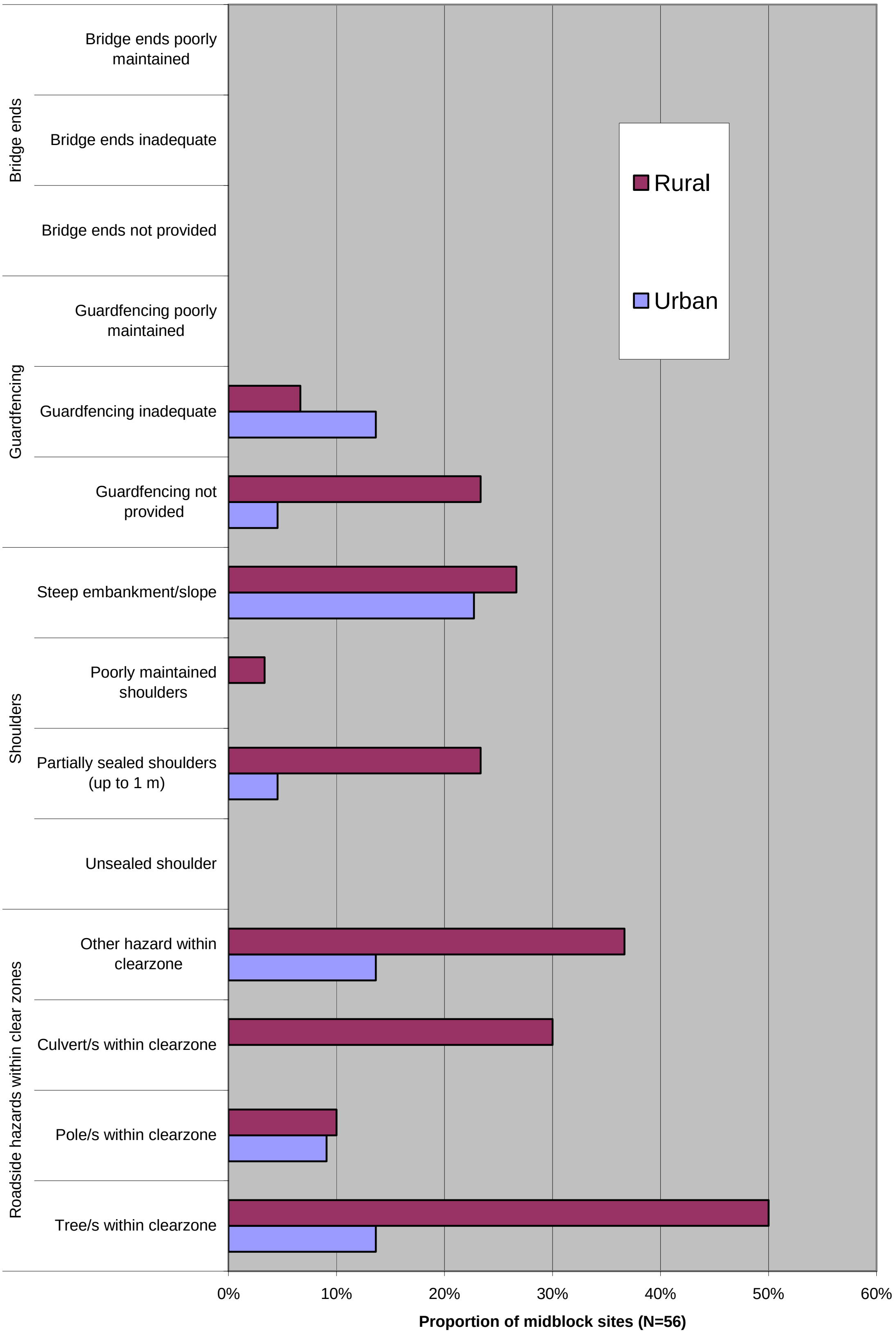


Figure D 1: Potential crash severity factors identified for midblocks

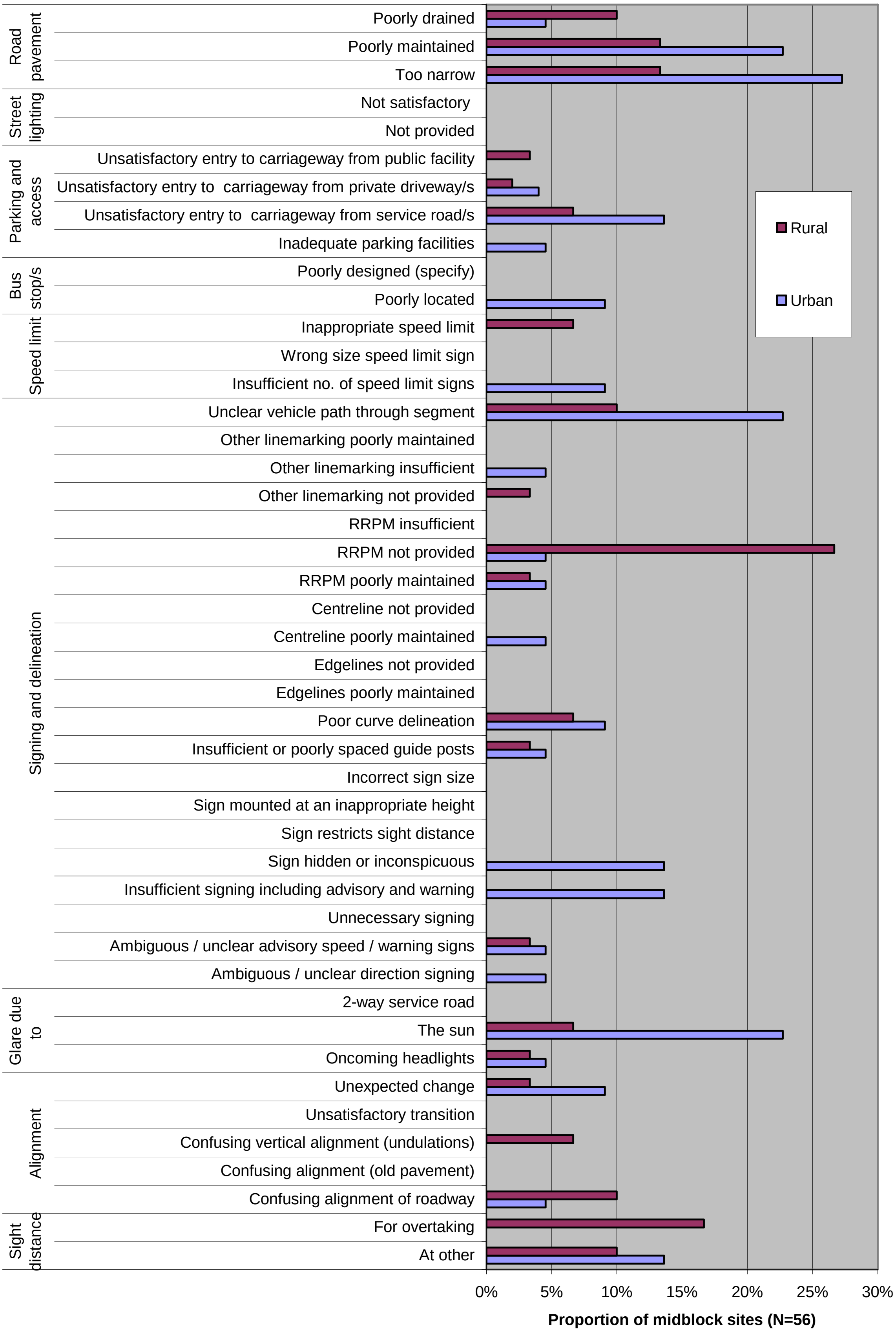


Figure D 2: Potential crash contributory factors identified for midblocks

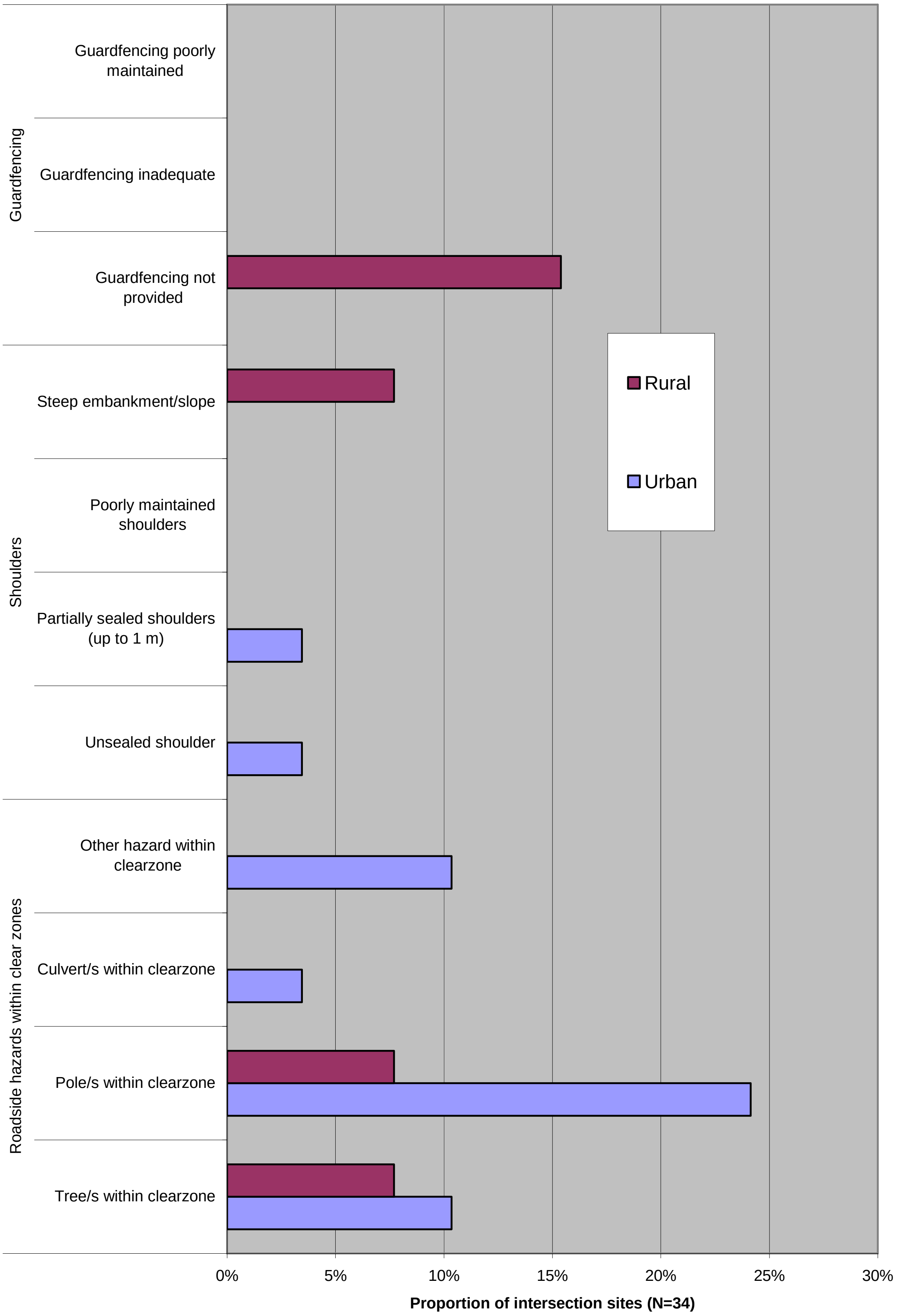


Figure D 3: Potential crash severity factors identified for intersections

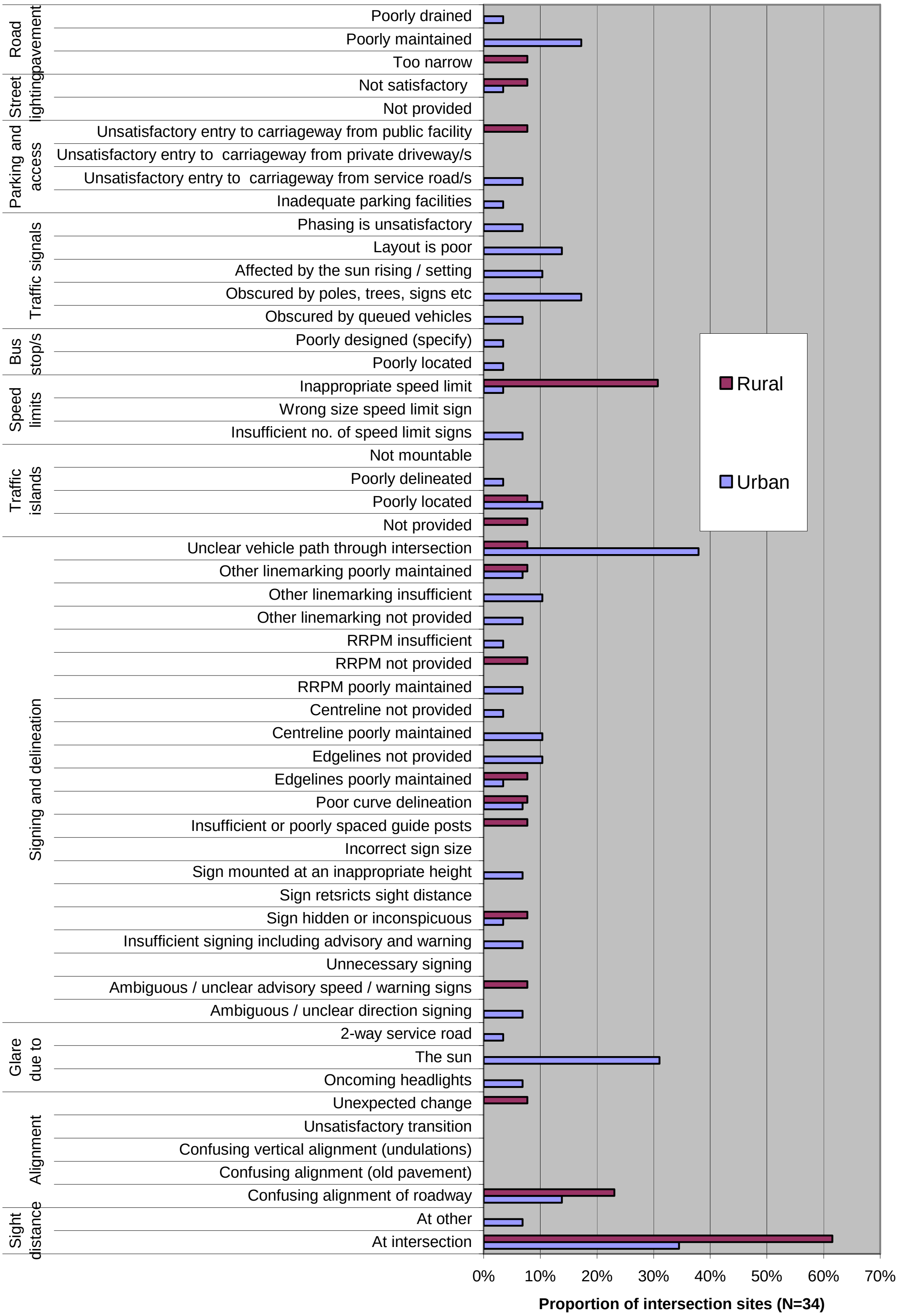


Figure D 4: Potential crash contributory factors identified for intersection

INFORMATION RETRIEVAL

Austroads, 2008, **Safety Benefits of Improving Interaction between Heavy Vehicles and the Road System**, Sydney, A4, 107pp, AP-T119/08

Keywords:

Heavy vehicle, crash data, road.

Abstract:

Heavy vehicle safety is a continuing concern in both Australia and New Zealand. On behalf of Austroads, ARRB Group undertook to identify the road related factors that contribute to heavy vehicle crashes on Australian and New Zealand freight routes. Four key tasks were carried out:

- an analysis of heavy vehicle crash data for New Zealand and all Australian jurisdictions except ACT
- inspections of heavy vehicle crash cluster sites along selected major freight routes aimed at identifying the road factors which may have contributed to the occurrence or severity of heavy vehicle crashes
- a review of literature focussed on the issues identified during the site inspections
- a stakeholder workshop.

These tasks all provided information which was used to guide recommendations for revisions to the Austroads Road Safety Audit Checklists and a draft strategy for addressing heavy vehicle safety on major freight routes.