Austroads

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Safe System Roads for Local Government

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Abstract

Australian and New Zealand local governments manage extensive road networks. Previous reporting indicates local government-managed roads represent 82 and 88% of the length of all public roads in both countries, respectively. As local roads, they tend to carry significantly smaller traffic volumes than the state road networks; however, analysis shows they contribute to more than half of all casualties resulting from road crashes, and an estimated 40 and 46% of fatalities.

The lower exposure combined with the relatively high proportion of casualty crash severity means the risk to drivers on local government-managed roads is estimated to be up to twice that faced on state roads.

Several factors combine to make implementing best practice Safe System infrastructure improvements a concern for local government. However, local councils are in a unique position of being able to harness the commitment and resources from across their organisations, including the elected representatives and local community, to support changes in road user attitudes as well as road planning, design, construction and maintenance to achieve incremental improvements that can make an impact on road safety and contribute to achieving national road safety objectives.

The Safe System Hierarchy of Control seeks to provide local government with a tool that can be used by technical and non-technical practitioners and that can be used to help communicate road safety risk and risk countermeasures to council management, elected representatives and the community.

Keywords

Local government, road safety, Safe System, risk management, Hierarchy of Control, Safe System Hierarchy of Control.

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About Austroads

Austroads is the peak organisation of Australasian road transport and traffic agencies.

Austroads' purpose is to support our member organisations to deliver an improved Australasian road transport network. To succeed in this task, we undertake leading-edge road and transport research which underpins our input to policy development and published guidance on the design, construction and management of the road network and its associated infrastructure.

Austroads provides a collective approach that delivers value for money, encourages shared knowledge and drives consistency for road users.

Austroads is governed by a Board consisting of senior executive representatives from each of its eleven member organisations:

- Roads and Maritime Services New South Wales
- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department of Planning, Transport and Infrastructure South Australia
- Department of State Growth Tasmania
- Department of Transport Northern Territory
- Territory and Municipal Services Directorate, Australian Capital Territory
- Australian Government Department of Infrastructure and Regional
- Australian Local Government Association
- New Zealand Transport Agency.

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Front cover image: ARRB Group

Summary

Australian and New Zealand local governments manage extensive road networks. Previous reporting indicate that local government-managed roads represent 82 and 88% of the length of all public roads in both countries, respectively. Local roads tend to carry significantly smaller traffic volumes than state road networks; however, analysis shows that they contribute to more than half of all casualties resulting from road crashes, and an estimated 40 and 46% of fatalities.

The lower exposure, combined with the relatively high proportion of casualty crash severity means that the risk to drivers on local government-managed roads is estimated to be up to twice that faced on state roads.

Several factors combine to make implementing best practice Safe System infrastructure improvements a concern for local government. However, local councils are in a unique position of being able to harness the commitment and resources from across their organisation, including the elected representatives and local community, to support changes in road user attitudes as well as road planning, design, construction and maintenance to achieve incremental improvements that can make an impact on road safety and contribute to achieving national road safety objectives.

The project aimed to develop a greater understanding of Safe System principles amongst local government practitioners and through this, increase application of the Safe System approach on local government-managed roads. The project had the following key components:

- identify cost-effective measures applicable to local government roads
- undertake a detailed analysis of crash data, identifying key issues by local road environment
- investigate a safety management system applicable to local roads
- incorporate outcomes from the project into the online practitioner reference tool, the Road Safety Engineering Toolkit
- consider the impact of project findings on relevant Austroads Guides.

The outcome is a report providing a detailed discussion of the findings of the analysis and investigations. This report also details the development of the Safe System Hierarchy of Control framework and discusses the enhancements to the Road Safety Engineering Toolkit. There is potential for the outcomes of the project to form the core of a Safe System-focused knowledge transfer workshop to assist local government practitioners to understand and apply the Safe System approach on their local road networks.

By taking into account all of the outputs of the project, local government will be better able to adopt best practice in many areas of road management, and make valuable incremental improvements towards achieving a Safe System on their network.

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1. Introduction

1.1 Purpose

The primary purpose of this project was the development of a greater understanding of Safe System principles by local government practitioners and subsequently an increased application of the Safe System approach on locally-controlled roads.

In developing the project, it was acknowledged there are a number of potential hurdles for local councils to adopting and delivering best practice Safe System solutions. However, it was also recognised that local government is in a very different situation to state and territory agencies when it comes to adopting a unified approach to road safety. Strategic action plans developed by local councils involve stakeholders from across the organisation, including strategic and land use development planners, road design and traffic engineers, road asset managers and community services staff, as well as elected councillors and the local community. This all-inclusive consideration empowers local government to adopt holistic road safety initiatives that allow incremental improvements to be made towards achieving a Safe System.

With this in mind, the project was comprised of several key components, delivered over a four-year period, with each contributing to the project purpose in different ways. The key components were:

- identify cost-effective measures applicable to local government-managed roads
- undertake a detailed analysis of crash data, identifying key issues by local road environment
- investigate a safety management system applicable to local government-managed roads
- incorporate outcomes from the project into the online practitioner reference tool, the Road Safety Engineering Toolkit
- consider the impact of project findings on relevant Austroads Guides.

The output of the project has been a series of reports assessing local government road safety issues, and discussing enhancements to practitioner tools and guideline information familiar to local government practitioners. These have been brought together in this report as a discussion about the Safe System approach and a suggested framework for evaluating road safety issues in a systematic manner that will assist to provide structured input to community consultations and also assist discussions with elected representatives and council management about road safety improvements.

There is potential for the output of this project to form the core of a Safe System-focused knowledge transfer workshop that designed to assist local government practitioners to understand and apply the Safe System approach on local road networks.

1.2 A Safe System Approach

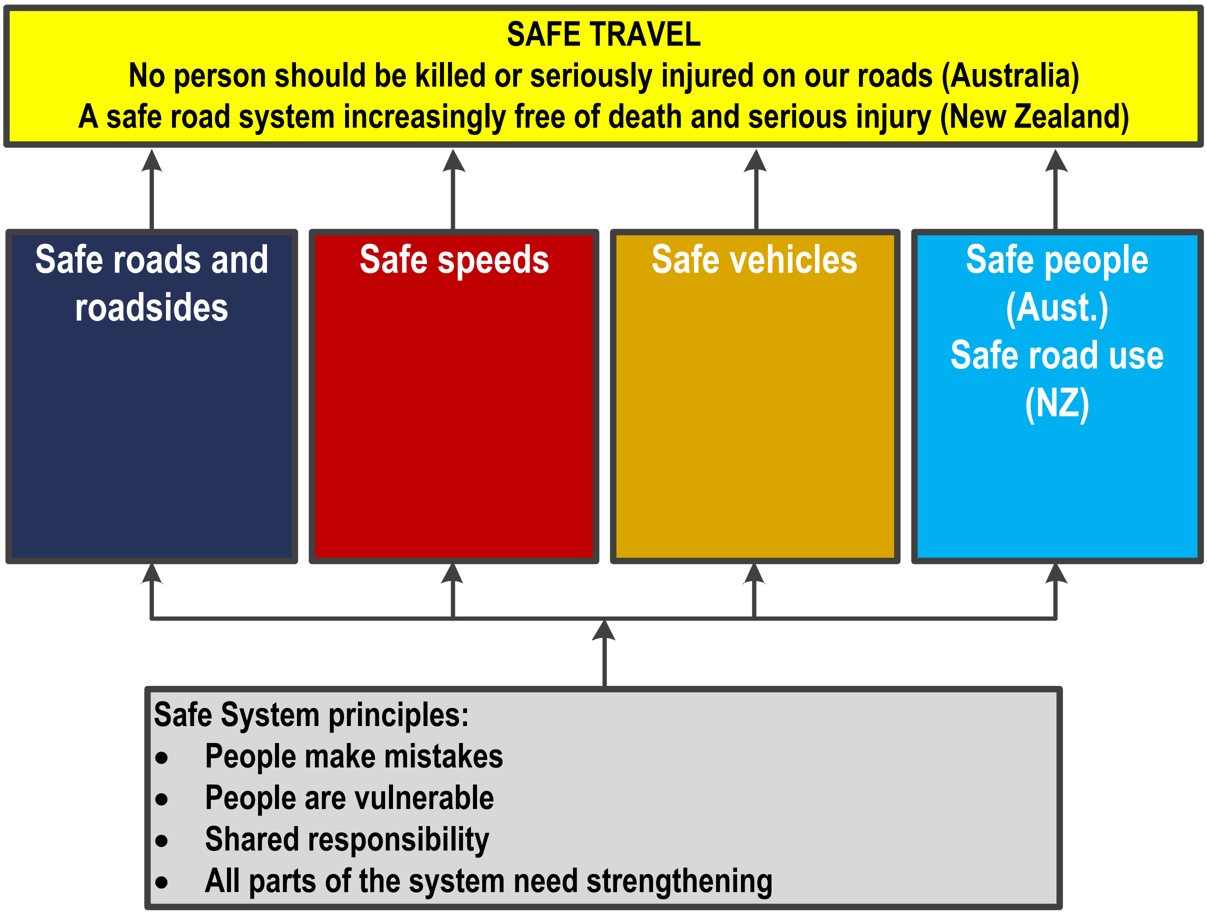
The Safe System approach is a guiding philosophy that is adopted by leading road safety nations. It is the foundation for road safety strategies and action plans adopted in both Australia and New Zealand since 2004, and is reiterated in the current road safety strategy documents for each country (Australian Transport Council 2011, Ministry of Transport 2010).

The Safe System approach operates on the principle that it is not acceptable for a road user to be killed or seriously injured if they make a mistake. The approach aims to create a forgiving road system based on the following four principles (NZ Transport Agency 2012):

1. People make mistakes – People make mistakes and some crashes are inevitable.
2. People are vulnerable – Our bodies have a limited ability to withstand crash forces without being killed or seriously injured.
3. We need to share responsibility – System designers and people who use the roads must share responsibility for creating a road system where crash forces do not result in death or serious injury.
4. We need to strengthen all parts of the road transport system – We need to improve the safety of all parts of the system, roads and roadsides, speeds, vehicles, and road use so that if one part fails, other parts will still protect the people involved.

The Safe System approach in Australia and New Zealand has four pillars where action can be taken to fulfil the above principles. There are a number of conceptual representations of the Safe System approach available. The framework illustrated in Figure 1.1 seeks to show the connection between the adopted vision, pillars and underlying principles in the Australian and New Zealand strategies.

Figure 1.1: Safe System approach framework



Source: ARRB Group.

1.3 Local Government-managed Roads and the Safe System

1.3.1 Characteristics of the Local Road Network

Austroads (2010a) found that local government manages approximately 82% of the Australian road network, and in New Zealand this is higher at 88%. The majority of the length of the Australian and New Zealand road network is rural local roads. In Australia, the majority of travel occurs on arterial (rural and urban) roads and state highways; while in New Zealand, approximately 50% of travel is on state highways (see Figure 1.2).

The majority of local government-managed roads are functionally urban or rural local roads, while only some arterial roads are managed by local government. It was noted that 'arterial roads managed by local government are generally those which connect smaller towns and cities' (Austroads 2010b).

Local government-managed roads typically cater for lower traffic volumes than the state road network and consist of a much more diverse range of road environments, ranging from high speed rural roads to local streets with residential and shopping functions and schools fronting them. Additionally, local government-managed roads tend to have a greater mix of road users present, particularly vulnerable pedestrians and cyclists.

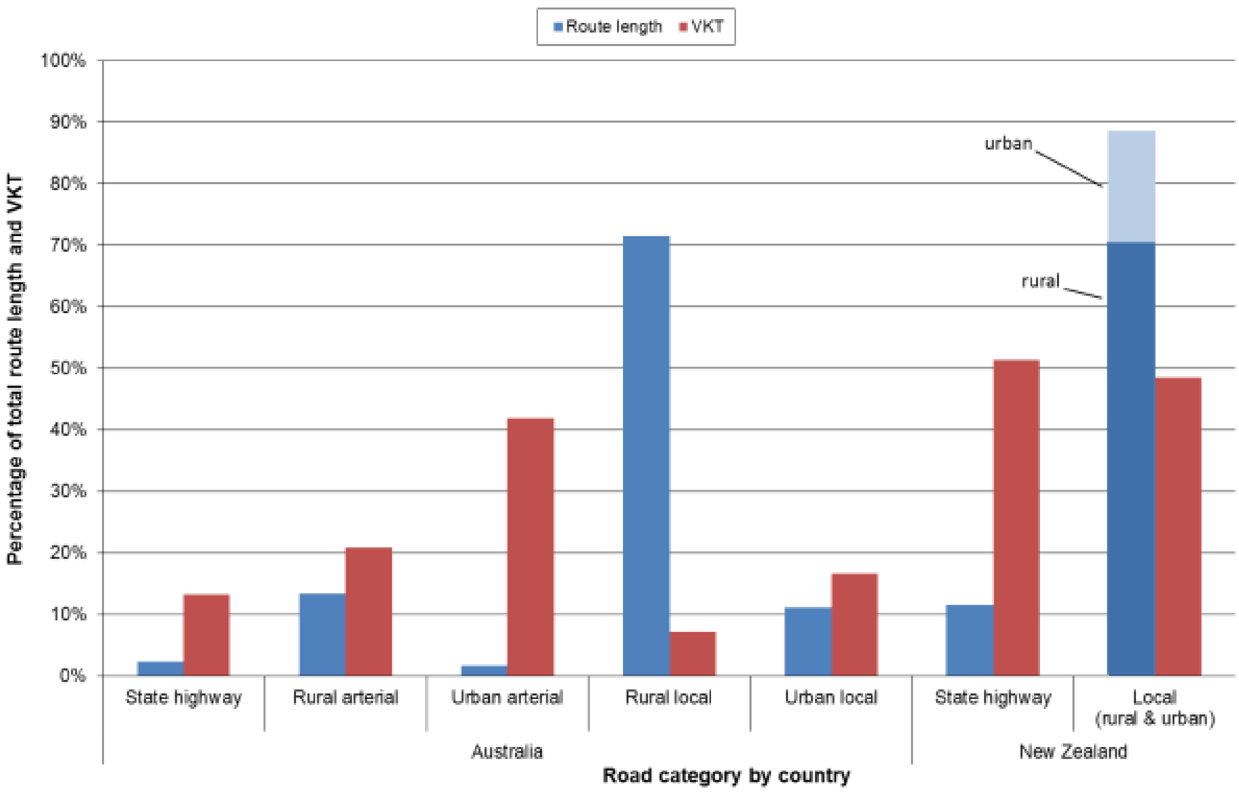
In Australia, 59% of the road network is unsealed; while in New Zealand, this figure is 35%. Austroads (2010b) goes on to conclude:

> Rural and low volume roads are more likely to be unsealed than urban and high volume roads. Therefore, as local governments are more likely to be responsible for rural local roads and low volume arterials, it is likely that local governments (particularly rural local governments) are responsible for a disproportionately large segment of the unsealed road network when compared with state governments.

and, further:

> Local roads, and unsealed roads in particular, are more likely than state managed roads to be characterised by:
>
> - a greater proportion of intersections and unsignalised rail crossings per km
> - low traffic volume, which sometimes has seasonal fluctuations
> - mixed traffic composition
> - poor road geometry
> - poor surface quality
> - inadequate delineation and advisory signing.

Figure 1.2: Percentage of route length versus vehicle kilometres travelled by road category



Source: Adapted from Austroads (2010a).

In terms of crash experience, the analysis reported in Austroads (2010a) found that 52% of all casualty crashes and 40% of all fatal crashes in Australia occur on local government-managed roads; while in New Zealand, these proportions are typically higher, at 66 and 46%, respectively.

As a result, the risk of drivers being involved in a casualty crash can be between 1.5 and 2 times higher than on the state road networks.

The findings of Austroads (2010a) highlighted several factors contributing to this crash experience and relatively higher risk on local government-managed roads, including:

- A general lower standard of design – poor junction design and road alignment, unsealed shoulders, narrow roads, a common presence of roadside hazards, a lack of delineation, inappropriate speed limits, and a lack of pedestrian facilities.
- Behavioural issues – excessive speeds, distraction, inattention, road user impairment, and driver expectations.

A number of constraints on local government were also identified as contributing to a poorer road safety performance. Treatment options are often restricted by financial factors and low benefit-cost outcomes, resulting in a lack of funding support internally and from state and federal agencies. This is often as a result of crash locations being more dispersed across a network, with clustering of crashes less likely to occur, or to involve much lower numbers, compared to state road networks; or treatments that may be developed under a proactive risk-based approach failing to achieve a required benefit-cost objective.

While Safe System principles are widely acknowledged, there is a gap in understanding how they apply to local government road networks, and it is often the case that the relatively cost-effective treatment measures available to local government do not achieve Safe System objectives.

Several of the recommendations contained in Austroads (2010a) define the scope of this project and are reflected in the key components listed in Section 1.1.

1.3.2 Local Government Contribution to the Safe System

Road safety treatment options that incorporate the Safe System approach and seek to deliver near zero deaths and serious injuries are defined as primary treatment options (Turner et al. 2009). Primary treatments are considered to be best practice Safe System solutions.

Other safety treatments are defined as supporting treatments; these reduce the likelihood of a crash but do not completely reduce the severity. Such treatments therefore do not conclusively eliminate fatal and serious injury (FSI) outcomes, but they are expected to be practical, easily installed, and improve road safety (Turner et al. 2009).

Supporting treatments have been widely used in the past decade and are useful tools in an incremental approach to crash reduction.

Where local governments may not be able to immediately deliver best practice (primary) Safe System solutions, Austroads (2010a) suggests they may instead be able to make incremental improvements towards achieving Safe System outcomes through use of supporting treatments.

The matter then is how local government practitioners are informed to identify the full range of Safe System treatments and road safety initiatives that address their road safety issue. There are a range of materials available that have been specifically designed to inform local government about how the Safe System approach can be applied to local government road safety issues.

Austroads (2010a) provides an overview of the ways that local governments are able to contribute to safety under the Safe System approach, as shown in Table 1.1.

Table 1.1: Contributions of local government road safety to the Safe System approach

Safe System factor	Local government contribution
Safe speeds	Where it is the responsibility of local government to manage speed limits on local roads: • review limits in response to changing land use and traffic • create low speed road environments • initiate local speed reduction campaigns • deploy movable vehicle speed feedback displays to reinforce speed limits • evaluate and communicate benefits of low speed road environments. Where responsibility for setting speed limits is outside of the jurisdiction of local government: • act as advocate to the relevant road authority for reduced speed limits.
Safe roads and roadsides	• provide appropriate roads and road lighting to fulfil traffic function • conduct traffic and transport planning to manage infrastructure provision into the future; ensure adequate provision for vulnerable road users and heavy vehicles • conduct road safety audits of new and existing facilities • identify blackspots, problem routes and areas, and develop plans to eliminate them over time • develop asset management plans to maintain safe conditions with regard to road surface, signs and delineation • manage vegetation in the roadside environment • develop pedestrian crossing management plans • establish processes for reporting and acting on road safety hazards • support older road users through attention to lighting, signage and delineation.
Safe vehicles	Council fleet: • have a safe driving policy in place that covers purchase of vehicles with good safety characteristics, fitness to drive, work and driving hours, and driver training • monitor fleet accident data; align safe driving with other OH&S policies. Local residents: • distribute information about infant and child restraints through clinics and health centres • distribute information about the safety benefits of buying cars with higher safety ratings and keeping cars well-maintained • engage the community to take ownership of the problem and finding solutions.
Admittance to the system	• support programs to assist the disadvantaged obtain a full licence • support the parents and mentors of learner drivers and learner drivers through a combination of education and practical experience.
Education and information for road users	• identify road safety issues specific to the community and develop targeted education campaigns • support alcohol, speed, and restraint and helmet use enforcement through media releases and education campaigns in partnership with the community • ensure council staff are aware of road safety issues, blackspot locations and other local casualty crash location patterns • educate the community about proposed road safety works and infrastructure changes.
Understanding crashes and risks	• collate information on road safety hazards • act as advocate for improvements on all roads affecting the community, especially local roads • investigate accident locations in partnership with other stakeholders • support direct action by community organisations to reduce high risk behaviours.
Legislation and enforcement	• support and encourage enforcement activities through media releases and education campaigns • develop enforcement programs using by-laws officers for high risk locations, e.g. parking at schools; coordinate enforcement with education and engineering programs.
Planning	• include road safety requirements in guidelines for developments • develop policies for cycle and pedestrian safety to ensure they will be considered in new developments or changes to land use • use developer contributions to fund road safety projects • include road safety in all council plans • include road safety audit as part of the planning and approval process.

Source: Austroads (2010a).

Austroads (2010a) reports the findings from analysis of crash data relating to local government-managed roads and feedback received from consultation with local government stakeholders. These findings outline key issues for road safety performance on council road networks, and discuss a range of potential actions to improve them. The report makes a number of recommendations for consideration by Austroads, several of which formed the scope for this project.

Via their RoadWise program, the Western Australian Local Government Association (WALGA) has led the way in developing and promoting the Safe System to local government in WA. Their *Safe System Guiding Principles for Local Government* publication (Western Australian Local Government Association 2012) promotes a whole-of-council approach to implementing Safe Systems. WALGA sees the Safe System approach as:

> ...a major shift from the road users to those who design, build and maintain the transport system. For road authorities, including Local Governments, planning and developing a safe transport system means looking beyond set standards and moving past the traditional role of constructing and maintaining roads; it means using Safe System treatments and countermeasures so that when people do make mistakes on the road network the outcome is less likely to result in death or serious injury. Along with the construction and maintenance of roads, Local Governments can influence road safety outcomes across each of the Safe System cornerstones through their responsibilities as a road authority, planning authority, employer and fleet operator.

The WALGA guide promotes six guiding principles for councils to adopt on the path to developing a Safe System approach for their road network and eliminating death and serious injury in their community. These principles are:

- Local government managers and elected members demonstrate leadership by valuing and progressing the Safe System approach.
- Local government integrates the Safe System approach into corporate and strategic plans.
- Local government ensures that Safe System policies and practices are proactive and evidence-based.
- Local government builds capacity at all levels of the organisation to effectively implement the Safe System approach.
- Local government utilises and examines relevant data to monitor and evaluate road safety performance.
- Local government fosters shared responsibility, internally and in external partnerships, for the implementation of the Safe System approach.

The NZ Transport Agency (NZTA) has also prepared material promoting the Safe System approach across local government disciplines. The New Zealand Safer Journeys Strategy seeks to promote roles and responsibilities for delivering a safe road network. Material outlining the role that land use planners, engineers, system designers, and the community have under a Safe System approach is freely available from the Safer Journeys website (www.saferjourneys.govt.nz/resources).

This project has sought to contribute to the understanding and application of the Safe System by local government through the development of a practical road safety issue/site assessment framework that builds on existing processes and knowledge readily available to practitioners.

1.4 Context and Structure of this Report

This report presents the outcomes of the project *Safe System Roads for Local Government*, with a detailed discussion of the findings and conclusions provided.

The structure of the report is as follows:

- Section 1 – provides the introduction, project purpose, scope and relevance to local government.
- Section 2 – outlines the findings of a literature review to identify cost-effective road safety treatments applicable to local government-managed roads.

- Section 3 – discusses the road safety performance of local government road networks based on analysis of crash data for Australia and New Zealand.
- Section 4 – presents the Safe System assessment framework developed for application to local government-managed roads and for use by local government practitioners.
- Section 5 – provides an overview of the changes made to the Road Safety Engineering Toolkit to incorporate the Safe System assessment framework and incorporate case study examples as a reference for practitioners.
- Section 6 – briefly identifies the suggestions for incorporating more local government content in the Austroads Guides.
- Section 7 – states the concluding remarks and suggestions for taking the project outputs to practitioners.
- Appendix A – provides a summary of the various treatments identified, with indicative relative costs and the Safe System pillar each one addresses.
- Appendix B– presents a sample of project case studies that illustrate the assessment framework.

1.5 Approved Safety Barrier Products

Safety barrier products referenced in this publication are included as examples of treatments used in different road environments and countries. Contact your local road agency for products approved for use in your jurisdiction.

2. Cost-Effective Treatments for Local Government-Managed Roads

A range of road safety treatment measures suitable for local government road environments have been identified via a review of Australian, New Zealand and international practice and research literature. The types of treatments, how well they achieve Safe System objectives, and the pillars they primarily address are discussed in this section.

To assist practitioners compare the relative cost and effectiveness of the identified treatments, they have been collated into a simple-to-read series of tables based on the type of road safety issues they are intended to address, which are presented in Appendix A.

The objectives of the literature review were to:

- identify cost-effective and innovative road safety treatment options suitable for application on local government-managed roads, high speed rural roads, and higher volume state-controlled roads
- review local area traffic management (LATM) measures suitable for application on local government-managed roads
- review emerging European approaches on speed reduction measures on local government-managed roads.

In establishing how well the identified road safety treatment options incorporate the Safe System approach and contribute to the of elimination of death and serious injury on the road network, reference has been made to the *Safe System Infrastructure: National Roundtable Report* (Turner et al. 2009). This report identifies primary and supporting Safe System treatment categories, with primary treatments being those that are considered to be best practice Safe System treatments.

Supporting treatments are those that reduce the likelihood of a crash but do not completely reduce the severity. Such treatments therefore do not eliminate FSI outcomes, however, they are expected to be practical and easily installed.

The information collated from this review has been used to update and expand the content of the Road Safety Engineering Toolkit, which local government practitioners are able to access at www.engtoolkit.com.au.

2.1 Findings from the Literature Review

The literature review was conducted using the resources of ARRB Group’s MG Lay Library, which coordinates the work of the National Interest Services (NIS) program. NIS is funded by the Australian federal, state and territory road agencies to support the provision of land transport information services in the national interest.

These resources included the Library’s own comprehensive collection of technical land transport literature and information retrieval specialists with extensive experience in the transport field, as well as access to the collections and expertise of other transport-related libraries throughout Australia and internationally.

Used specifically in this literature search were the Australian Transport Index (ATRI) and Transportation Research Information Documentation (TRID) databases, whose content is coordinated by ARRB Group and the Organisation for Economic Co-operation and Development/US Transportation Research Board, respectively. Use of these databases ensured wide coverage for quality research material within the subject area from national and international sources.

2.2 Road Safety Treatments for Cyclists

The Austroads *Guide to Road Design Part 2: Design Considerations* (Austroads 2015a) states that it is important to consider the needs of all road users, including cyclists, pedestrians and non-motorised traffic. In the design of cycle facilities, the aim should be to separate cyclists from vehicles either through the use of off-road paths or dedicated cycle lanes along the roads.

Austroads (2010b) considers seven types of cycle facilities, listed in order of the level of safety and priority:

1. Off-road dedicated cycle path.
2. On-road segregated cycle lane.
3. On-road dedicated cycle lane.
4. On-road peak period dedicated cycle lane.
5. On-road cycle/car parking lane.
6. Wide kerbside lane.
7. Narrow kerbside lane.

This section describes on-road facilities, particularly methods to achieve better separation of cyclists while maintaining their connectivity and not impeding the movement of other road users.

2.2.1 Off-road Dedicated Cycle Lanes

As indicated by Austroads (2010d), off-road cycle lanes are the optimal cyclist treatment in terms of safety and priority. When situated within the road corridor, exclusive off-road paths are a comfortable and safe solution while maintaining a high level of connectivity afforded by being part of the road network. When designing off-road cyclist facilities, the needs of pedestrians should be considered. The lane width required may be different for shared paths and dedicated cycle paths, and the transition from off-road to on-road paths should be designed such that cyclists are not directed into the traffic stream at high speed. In many areas, however, it will not be possible to construct off-road paths due to space restrictions.

Off-road cycle paths and shared paths are described in more detail in Austroads *Guide to Road Design Part 6A: Pedestrian and Cyclist Paths* (Austroads 2009a).

2.2.2 Separated Cycle Lanes

One method of creating better separation of cars and cycles is to relocate the cycle lane to the kerbside of parked vehicles. Copenhagen style cycle lanes and kerbside cycle lanes are two main types of separated cycle lanes identified in the literature review. Each is briefly discussed below.

Copenhagen style cycle lanes

Copenhagen style cycle lanes consist of a built median or kerb separation of cyclists from the travel lanes. In many cases, there is also provision for parking in between the cycle lane and traffic lanes.

A Copenhagen style lane was installed on Swanston Street in Melbourne in 2007 (Figure 2.1). The design involved a two metre wide cycle lane next to the kerb, with a one metre wide median island and parking lane providing clear separation to vehicle traffic. The median also allows passengers to open parked car doors without impacting on the cycle lane. The design was replicated on the other side of the street. A traffic survey conducted in 2007 found that 80% of cyclists enjoyed the increased separation and that 45% of cyclists rode more often as a result of the treatment (Alta 2010).

Alta (2010) estimated that the cost of Copenhagen style cycle lanes was $280 per metre (based on the cost of installing this treatment in Melbourne).

Figure 2.1: Copenhagen style cycle lanes along Swanston Street, Melbourne

Source: Bicycle Network (2013).

Kerbside cycle lanes

Separated kerbside cycle lanes are a simpler and cheaper version of the Copenhagen style lanes. This design also has a kerbside cycle lane, but it is separated from traffic by a parking lane and a traversable element such as a flushed median, vibraline, rumble strips, or plastic lane separators (Alta 2010). This extra buffer is designed to prevent cars from parking in the cycle lane and to prevent car doors from encroaching into cyclist space.

A number of kerbside cycle lanes have been installed in the USA in an attempt to provide better protection for cyclists and a more efficient use of road space. In Minneapolis, cycle lanes were added to the kerbside of parked cars on a busy arterial road. Its goal was to encourage casual and lower-skilled cyclists to ride more often, by providing safer and better connected cycle networks.

After six months, the volume of cyclists rose by 43% across the treatment corridor, and cyclist crashes dropped from 12.25 crashes per year to zero. In New York, a kerbside running cycle lane added along Grand Street accounted for a 29% increase in cycle riders and after one year, cyclist crashes dropped by 27% (Alta 2010).

In 2010, the City of Melbourne installed a kerbside cycle lane along Albert Street. The design consists of a 1.4 m cycle lane with a 0.8 m painted buffer zone including audio-tactile line marking and flexible bollards (Figure 2.2). This treatment was estimated to cost $70–$150 per metre (Alta 2010).

Figure 2.2: Kerbside cycle lane in Albert Street, Melbourne

Source: Alta (2010).

2.2.3 Narrow Separation Treatments

Another style of separator, the Riley Kerb, was trialled in Christchurch, New Zealand (Wilke 2012), as shown in Figure 2.3. The separator was designed to be safe for cars to drive over, with gaps between devices enabling cyclists to move into and out of the lane.

Vehicle encroachment on the cycle lane was measured before and after the treatment and it was found that the percentage of vehicles encroaching on the cycle lane dropped from 41 to 2%.

Figure 2.3: Riley Kerb treatment in Christchurch, New Zealand

Source: Wilke (2012).

A number of other on-road treatments have been implemented to reinforce cycle lanes, including audio-tactile edge lines and provision of wide cycle lanes adjacent to parking with a narrow painted median (Figure 2.4). The painted cycle lane with audio-tactile edge line was estimated to cost $50 per metre (Alta 2010).

Figure 2.4: Narrow separation treatments

a. Cycle lane with audio-tactile line.
Source: Bicycle Network (2013).

b. Wide cycle lane with narrow median.

2.2.4 Painted Cycle Lanes

Cycle lanes are often painted a different colour to distinguish them from the rest of the road environment. While a number of colours have been trialled, there is an agreement among Australian road agencies to use green surfacing for cycle facilities (VicRoads 2005), although Austroads recommends that green surfacing should be used sparingly to maintain its effectiveness (Austroads 2010b). Skid resistance should remain comparable to the other traffic lanes in all weather conditions.

A number of studies have attempted to quantify the benefits of this treatment, both in terms of vehicle encroachment and in the proportion of vehicles giving way at conflict points. In a trial of painted lanes near conflict points in Melbourne, the proportion of vehicles conflicting with cyclists at three sites dropped from 28 to 3%, and there was a reduction from 39 to 20% in the proportion of vehicles encroaching into the cyclist storage box at intersections (SKM 2011). Another study found the proportion of yielding motorists increased from 72 to 92% where the painted cycle lane crossed side-roads or off-ramps (Hunter et al. 2000).

A study of painted cycle lanes at intersection approaches in New Zealand found a 39% reduction in cyclist injury crashes (Austroads 2011), while a study in Denmark found a 38% reduction in cyclist crashes and a 71% reduction in serious and fatal crashes (Jensen 1997). Elvik et al. (2009) estimated that coloured cycle lanes reduced all crashes by 2% and cyclist crashes by 22%.

2.2.5 Advanced Stop Line

Advanced stop lines for cyclists at signalised intersections may help make cyclists more visible to motorists. Elvik et al. (2009) estimated that this treatment is associated with a reduction of 16% for all crashes, 19% for cycle crashes and 11% for motor vehicle crashes.

2.2.6 Road Diets

A road diet involves removing traffic lanes to provide space for other road users such as cyclists and pedestrians. Road diets may involve incorporating one or a number of combinations of on-street parking, cycle lanes, medians, pedestrian crossing facilities and turning lanes.

Burden and Lagerwey (1999) outlined the warrants for a road diet scheme, as follows:

- moderate traffic volumes (8000 AADT–15 000 AADT)
- roads with road safety issues
- popular or essential cycle routes
- entertainment districts and main streets with a large number of pedestrians.

2.2.7 Summary

In areas where cyclists make up a significant proportion of traffic, or on parts of the principle cycle network, it is advisable to provide a dedicated cyclist facility. This may be in the form of off-road cycle lanes, either shared with pedestrians or as dedicated cycle paths.

This treatment creates the most separation from other traffic, however, it requires more space and care has to be taken when merging back to a shared environment. When cycle facilities are installed along the road, there are a number of methods to give better protection for cyclists while not impeding the movement of vehicular traffic. Many of these methods are inexpensive and should be considered by local governments.

2.3 Median Treatments

A median can be defined as a 'strip of road…which separates carriageways for traffic in opposite directions' (Austroads 2015b). Wide medians are mostly used along arterial roads (including freeways and highways). Narrow medians are used along distributor, collector and local roads, and along some arterial roads. Median design is based upon its location, available space, traffic volumes, level of service, safety considerations, and user priority along the road in question.

Medians are installed as part of the original road design, or can be retrofitted at a later stage. Its main purpose is to separate opposing flows of traffic. However, medians can be used to separate different road users such as cyclists and pedestrians. The functions of medians as described in Austroads (2010a) are to:

- separate and reduce conflict between opposing traffic flows, effectively reducing the possibility of head-on collisions
- prevent indiscriminate crossing and turning movements
- shelter right-turning and crossing vehicles at intersections
- shelter road furniture and traffic control devices, such as signs, traffic signals and street lighting
- provide a pedestrian refuge which enables pedestrians to cross the road one carriageway at a time
- reduce the impact of headlight glare and air turbulence from opposing streams of traffic
- provide scope for improvement of visual amenity by landscaping
- accommodate level differences between carriageways
- provide a safety barrier
- provide an emergency stopping area on multi-lane roads
- provide a recovery area for errant vehicles.

There are a number of different styles of median and these will be described in the following sections.

2.3.1 Constructed or Raised Medians

Charlton et al. (2010) utilised raised medians in combination with centre and edge lines, cycle lanes and pedestrian crossings on a selection of collector roads in Auckland, New Zealand. The purpose of the study was to make collector roads clearly distinct from local roads, i.e. self-explaining roads. The inclusion of landscaped medians also contributed to reducing lane widths to manage vehicle speeds. Within the study area, three collector roads were treated and one was left untreated as the control. Mean speed reductions of between 2–3 km/h were observed across the treated roads. However, there was less speed variability across the treatment sites, with fewer drivers exceeding 70 km/h after the treatments were implemented.

2.3.2 Flush Narrow Medians with Flexible Barriers

Austroads (2014b) included a literature review of flush narrow medians with flexible barriers. The review revealed that this median treatment improved safety, particularly relating to higher severity crashes. Table 2.1 presents the crash reduction factors associated with flexible median barriers on undivided rural highways (Austroads 2014a).

Table 2.1: Summary of effectiveness of flexible median barriers on undivided rural highways

Crash type	Effectiveness and sources
• All types, mid-block sections only	• 46% FSI crashes on 110 km/h roads (Gan, Shen & Rodriguez 2005) • 74% FSI crashes on 90 km/h roads (Gan, Shen & Rodriguez 2005)
• Run-off-road to right and head-on	• 70% casualty crashes (Austroads 2009b)
• All crash types	• 28% casualty crashes (Austroads 2009b)

Source: Austroads (2014a).

A 2 + 1 design with a 1.5 m flush median and flexible barrier was used in Sweden and found an associated reduction of over 75% in fatalities (Larsson, Candappa & Corben 2003).

2.3.3 Flush Medians with Rumble Strips

Narrow, one metre wide painted medians consisting of yellow rumble lines were trialled in Norway on an 80 km/h speed limit rural highway, as shown in Figure 2.5 (Sagberg 2006). The before and after speed analysis revealed a 2.7 km/h reduction in mean speed. Sagberg (2006) concluded that although there were no changes to lane widths, the speed reductions could be explained by increased driver workload as a result of the perception that the lanes were narrower. Cars and heavy vehicles were also recorded to be travelling approximately 35 cm further from the centreline of the road after the introduction of the median, which was concluded to have improved the safety margin for head-on crashes.

Figure 2.5: Rumble strip painted median, Norway

Source: Sagberg (2006).

Levett, Job and Tang (2009) reviewed the effectiveness of narrow median treatments with audio-tactile line marking on the Pacific Highway in NSW. These median treatments ranged from 0.5 to 1.0 m wide (total treatment length of 1.16 km). The authors found that the audio-tactile line marking reduced crashes and suggested a width of at least 1.0 m for high volume highways.

These findings are in line with those observed from a similar trial on the Newell Highway in NSW that involved two 5 km lengths of a narrow 1.0 m median with audio-tactile line marking. The Newell Highway trial found a considerable reduction in vehicles drifting from the lane (for both the edge and centre lines), as well as a reduction in mean vehicle speeds (Connell et al. 2011).

2.3.4 Flush Medians with Channeliser Posts

Hallmark et al. (2008) studied the effects of longitudinal channelisers installed in a median along a rural highway entering the small town of Slater in Iowa, USA (Figure 2.6). The main aim of the treatment was to reduce the speed of vehicles entering the township by reducing lane widths. They provided a physical buffer whilst allowing for driver error without causing serious damage to vehicles. The islands included speed limit signs to remind drivers of the reduced speed limit through the town. The treatment was associated with a reduction of both the 85th percentile speeds and mean speeds through the town.

American Traffic Safety Services Association (2011) highlighted a number of areas where channeliser posts may be installed. These include use:

- on the approach to railway crossings to discourage driving around lowered boom-gates. The treatment was found to be very effective in a number of US studies, with a reduction of violations between 77–100%
- as traffic calming devices in rural towns to create traffic islands
- in median breaks to either close the median, or restrict turning movements from both directions to one direction only. An evaluation of using this device to restrict turning movements at medians to one direction found a 60–70% reduction in left-turn (right-turn in Australia and New Zealand) crashes. The treatment was estimated at $25 000 per location.

Figure 2.6: Flexible channelisers in Slater, Iowa

Source: Krammes and Sheldahl (2009).

2.3.5 Summary

The main purpose of a median is to separate opposing traffic streams and to reduce the risk of head-on crashes. Medians can decrease the number of FSI crashes; however, they can also lead to an increase in minor crashes and property damage only crashes.

Flush medians have the benefit of being cost-effective to implement and maintain (compared to a constructed median), as well as providing additional space for errant vehicles. Wider medians also provide emergency stopping areas, sheltered turning areas and recovery zones for errant vehicles.

In rural environments, narrow flush medians incorporating audio-tactile line marking led to crash reductions and reduced mean speeds.

Raised medians are more expensive, but can enforce lane discipline, restrict certain turning movements and provide a physical barrier between opposing traffic streams. A constructed median can sometimes be considered a hazard to vehicles. An alternative option to a constructed median is the use of longitudinal channelisers, which provide a physical barrier whilst only resulting in low damage when errant vehicles collide with the treatment. The channelisers have also been found to have a positive effect on reducing mean vehicle speeds (Hallmark et al. 2008).

2.4 Road Safety Treatments for Pedestrian Crossing Safety

Over 10% of crashes on urban local roads are pedestrian crashes. Reduced speed limits of 40 and 50 km/h on local roads may reduce the likelihood of severe injury outcomes for vehicle occupants, but pedestrians still face a significant risk of fatal and serious injuries at those speeds.

The following review is focused on treatments at signalised and unsignalised locations, including mid-block crossings and at unsignalised intersections between arterial roads and local streets.

2.4.1 Puffin Crossings

Puffin (Pedestrian User Friendly Intelligent) crossings are a modified version of the traditional signalised pedestrian crossing. The aim of puffin crossings is to allocate more time to pedestrian crossing movements when required, and to also cater for more efficient traffic movement by cancelling unnecessary pedestrian phases (Department of Transport 2006). This is achieved with cameras mounted next to the signals, which can detect the presence of pedestrians on the crossing. Puffin crossings have pedestrian signals mounted on the nearside, which is intended to direct the attention of pedestrians to approaching traffic as they wait to cross (see Figure 2.7).

The Department of Transport (2006) presented the findings of a number of studies that assessed the effectiveness of Puffin crossings, including:

- an 83% reduction in pedestrian crashes across five sites converted to Puffin crossings (Walker et al. 2005)
- a study by Webster (2006) found that at sites converted to Puffin crossings, total crashes had reduced by 39% and pedestrian crashes had reduced by 30%. Converting Zebra crossings to Puffin crossings resulted in a reduction of 14% for total crashes and 8% for pedestrian crashes. New Puffin crossing installations resulted in a 35% reduction in pedestrian crashes.

Catchpole (1995) evaluated the driver and pedestrian behaviour at a trial Puffin crossing in Victoria. There were some improvements in pedestrian compliance with the signals, while there was no statistically significant impact on red light running by drivers.

Figure 2.7: Nearside Puffin pedestrian display in the United Kingdom

Source: Department of Transport (2006).

In response to concerns from some pedestrians that they would prefer to see the ‘green walk’ signal while they were on the crossing, Transport Research Laboratory (TRL) funded a trial of modified Puffin crossings that incorporated far-side signals in addition to the nearside signal (Maxwell et al. 2011). Public opinion of the modified design was favourable, but the far-side signals led to red light violations by both pedestrians and vehicles. Following the trial, the far-side signals were removed and the original design maintained. Campaigns to educate pedestrians on the use of Puffin crossings were encouraged.

2.4.2 Pedestrian Countdown Timers (PCT)

A number of countries use countdown timers on the pedestrian signals to inform pedestrians of the time remaining to finish their crossing. In the most common design, the ‘flashing red’ phase is replaced with a red countdown clock. While this treatment is usually not installed purely as a safety device, surveys of installations show that pedestrians prefer the countdown clock to the conventional crossing signals.

A trial of PCT was undertaken at two sites in the Sydney CBD in 2010 (Levasseur & Brisbane 2011); see Figure 2.8. Video analysis was used to determine changes to pedestrian behaviour after the installation of the countdown timers. The study found that there was a 12% increase in late starters at the wider crossing, although they were found to walk faster than before, which meant that there was minimal change in the proportion of late finishers. The reaction to the PCT was favourable; 78% of respondents felt that the PCT made the crossing ‘a little’ or ‘much safer’, while 63% felt the PCT made the crossing ‘easier to understand’.

Across three inner suburban sites in Melbourne, a study found no reliable indications of improvements to pedestrian behaviour, although the results varied across the sites (Cairney et al. 2010). Surveys indicated that 36% of pedestrians felt that the PCT made the crossing safer, with 39% advocating more PCT installations.

Although there are benefits to using PCT, there is limited application of PCT on local roads in Australia. Local governments do not implement PCT schemes as they fall under the jurisdiction of state road agencies.

Figure 2.8: Pedestrian countdown timers in Sydney CBD

Source: Levasseur and Brisbane (2011).

2.4.3 Pedestrian Refuge Islands

A pedestrian refuge island is a raised median island in the middle of the road, with space provided for pedestrians to wait for a safe gap in traffic before completing the crossing. A refuge allows a pedestrian to stage their crossing, so that they only need to cross one traffic direction at a time, as opposed to attempting to cross a full width carriageway with traffic in both directions. Refuges are particularly beneficial for the elderly, school children and disabled persons who may otherwise find it difficult to cross the street safely. Refuges can also be combined with pedestrian fences on busy streets. Some refuge island designs also act as a median island that narrows the vehicle travel path and may have a speed reduction effect.

Pedestrian refuges can be incorporated into mid-block median treatments, centre blister islands and slow points, as well as at intersections with left-in/left-out islands and intersection medians (Austroads 2008).

A study in Warringah Shire (NSW) found that 85th percentile speeds had reduced from 71 to 62 km/h after the introduction of a pedestrian refuge (Hawley et al. 1992). At this site, the road was realigned and carefully designed to create a slow point at the refuge island.

Jurisich et al. (2003) investigated the safety performance of pedestrian refuges on flush medians in Auckland. A total of 23 crashes were identified involving pedestrians at refuge islands. The most common type of crash was pedestrians stepping out from the refuge into the path of oncoming traffic. There were also a number of rear-end crashes where cars had stopped to give way to pedestrians at a refuge island. The authors suggest that there was some confusion among drivers about the role of a refuge island as opposed to a zebra crossing.

Austroads (2012) recommended a crash reduction of 45% for pedestrian refuges.

2.4.4 Wombat Crossings

Wombat crossings consist of a raised platform with a marked pedestrian crossing on top, as well as a central refuge and kerb blisters if space permits (Figure 2.9). Pedestrians have priority at wombat crossings. The raised crossing serves the purpose of slowing vehicles and increases the visibility of pedestrians due to the increased height. Wombat crossings have similar dimensions to road platforms, with more gradual ramps and longer flat sections recommended on bus and cycle routes (Austroads 2008). It is important that wombat crossings and flat top road humps are marked correctly, as crashes can occur if there is confusion about priority between vehicles and pedestrians.

Figure 2.9: Wombat crossing in Knox, Victoria

Source: Austroads (2008).

Wombat crossing trials have shown that these devices can result in lower mean and 85th percentile speeds along treatment routes.

A study on two collector roads in the Australian Capital Territory (Department of Territory and Municipal Services 2006) that included three wombat crossings, along with two chicanes and a speed platform, found mean speeds dropped by between 3 and 10 km/h and 85th percentile speeds by between 5 and 9 km/h. It also had the effect of lowering traffic volume by 12% on one road, with no significant difference on the other. A review of wombat crossings in Austroads (2012) recommended a reduction of 20% for pedestrian crashes associated with the installation of this treatment.

2.4.5 Pedestrian Safety Treatments at Unsignalised Crossings

Authorities in the USA have trialled a number of innovative pedestrian treatments for unsignalised crossings. These include overhead flashing beacons, in-roadway warning lights, enhanced warning signs and enhanced crossing markings. The Transit Cooperative Research Program (TCRP) and the National Cooperative Highway Research Program (NCHRP) undertook a joint study into the effectiveness of various safety treatments at unsignalised pedestrian crossings (Fitzpatrick et al. 2006). Compliance was highest with systems that incorporated red signal or beacon treatments, similar to mid-block signalised pedestrian crossings found in Australia or Puffin crossings in the UK.

Flashing overhead crossing signs, such as those shown in Figure 2.10, comprise of one or more flashing beacons mounted above the roadway to alert drivers to the presence of a pedestrian attempting to cross (Fitzpatrick et al. 2006). The beacon can either be activated through sensors under the footpath or through push-button controls. This treatment can lead to some improvement in the proportion of motorists yielding at unsignalised crossings, especially where there are fewer lanes and where there are lower speed limits. These treatments were less effective on higher speed roads with more lanes, leading to an average compliance of 31–74%, which is significantly below that of red signal controls.

Figure 2.10: Flashing overhead crossing lights in the USA

Source: Fitzpatrick et al. (2006).

In-street pedestrian crossing signs are used across the USA at unsignalised pedestrian crossings (Fitzpatrick, Turner & Brewer 2007). The sign can incorporate a give-way or stop sign, in accordance with local laws. This treatment was studied at seven sites in the USA with the device shown in Figure 2.11. Vehicle compliance rose from 69.8 to 81.2% (Huang et al. 2000).

Figure 2.11: Examples of in-street pedestrian crossing signs

Source: Federal Highway Administration (2013), Huang et al. (2000).

In-roadway warning lights were installed at a crossing in New Jersey (USA) to increase the conspicuity of pedestrians and reduce conflicts (Van Derlofske, Boyce & Gilson 2003). The design includes improved striping and sensor activated flashing warning lights across the roadway (Figure 2.12).

This treatment was found to enhance the noticeability of the crossing and reduce the number of vehicle-pedestrian conflicts. Striping alone did not improve vehicle compliance or mean speed through the crosswalk; however, adding the warning lights marginally reduced the mean approach speed and led to fewer vehicles driving through the crossing while a pedestrian was waiting. In-roadway lights require regular maintenance and periodic replacement.

Figure 2.12: In-roadway warning lights in New Jersey, USA

Source: Van Derlofske, Boyce and Gilson (2003).

In-street pedestrian crossing warning lights were also trialled in New Zealand (Smith, Pinkney & Tse 2008) at three sites with varying pedestrian safety concerns. The lights were installed along the centreline of the road, as well as across the width of the road near the control line, and were activated by a photoelectric detection system. The trial also included raising the pedestrian crossings to improve visibility. The study found that the proportion of drivers stopping for pedestrians rose from 5 to 21%, and conflicts dropped from 2% to almost zero. The study also found a reduction in mean speeds and 85th percentile speeds.

Fitzpatrick et al. (2006) amalgamated the results from five in-roadway warning light studies covering eleven sites and found that vehicle compliance ranged from 8–100%, with an average of 66% compliance.

Another potential treatment is the HAWK (High intensity Activated crossWalK) beacon signal. The HAWK incorporates an overhead traffic control signal that is dark until activated by a pedestrian control button, when it turns flashing yellow, followed by solid yellow and then solid red. After a programmed crossing time, the signal moves onto flashing red, at which time vehicles are allowed to proceed through the intersection provided there are no pedestrians still in the crossing.

The HAWK was developed in response to poor compliance rates with other unsignalised crossing treatments. The Fitzpatrick et al. (2006) study found that vehicle compliance rates averaged 97% for HAWK crossings.

Figure 2.13: HAWK crossing at an unsignalised intersection

Source: Fitzpatrick et al. (2006).

2.4.6 Other Improvements at Unsignalised Crossings

Minor improvements such as setback control lines at crossings, especially on multi-lane roads, can improve the line-of-sight for vehicles and pedestrians.

Road diet designs may also lead to pedestrian safety improvements, for instance, through incorporation of pedestrian facilities. The added space created from removing one lane of traffic can be allocated to cycle lanes.

2.5 Delineation on Rural Roads

Run-off-road crashes account for a significant proportion of rural casualty crashes in Australia and New Zealand. There are a number of innovative and low-cost infrastructure treatments that can be implemented on locally-controlled rural roads or at the junction of high and low volume rural roads.

High quality delineation is important on rural roads as it assists drivers in keeping their vehicles on the roadway. Poor delineation can increase the likelihood of run-off-road crashes on curves or of head-on and side-swipe crashes on straight sections. The two broad treatment categories considered are line markings and advanced warning treatments for curves or hazards.

2.5.1 Illuminated Pavement Markers

Illuminated pavement markers were tested at various sites across Victoria (Styles et al. 2003). The markers were solar powered and were activated during low light conditions. The markers encouraged drivers to travel at a reduced speed and improved their lane discipline. A TRL study revealed that the illuminated markers installed at right hand bends resulted in improved road safety, as shown in Figure 2.14 (Reed 2006).

Figure 2.14: Installation of actively illuminated pavement markers

Source: Reed (2006).

2.5.2 Transverse Lane Markings

Transverse pavement markings generally consist of transverse bars, chevrons or 'dragons teeth' markings on the approach to a curve or hazard, or as a transition treatment at a rural threshold. This treatment is commonly used along activity centres in urban areas in the UK (Hallmark, Hawkins & Knickerbocker 2013).

Hallmark, Hawkins and Knickerbocker (2013) reviewed a range of different transverse lane marking treatments. These markings give drivers the perception that they are speeding up and encourage them to reduce their vehicle speeds (Figure 2.15). These line markings are inexpensive to install and do not require any further road design changes.

Figure 2.15: Various styles of transverse line markings

Source: Hallmark, Hawkins and Knickerbocker (2013).

Different types of transverse line marking and their effectiveness are presented in Table 2.2.

Table 2.2: Transverse line marking studies

Reference	Location	Style of markings	Mean speed reduction	85th percentile speed reduction
Hallmark et al. (2007)	Iowa, USA	Peripheral transverse speed bars	Up to 2 mph (3.2 km/h)	Up to 2 mph (3.2 km/h)
	Iowa, USA	Converging chevron pattern	Up to 3 mph (4.8 km/h)	Up to 4 mph (6.4 km/h)
Hallmark, Hawkins and Knickerbocker (2013)	Iowa, USA	Triple transverse bars	Between 1 mph (1.6 km/h) increase and 2.3 mph (3.7 km/h) decrease	Between 2 mph (3.2 km/h) increase and 2 mph (3.2 km/h) decrease

Source: ARRB Group.

2.5.3 Coloured Surface Treatments

Another method of alerting drivers to an upcoming hazard or change of road environment is to use painted or textured surfaces on the roadway. This is commonly used in conjunction with gateway treatments, or to emphasise the presence of a traffic calming device, such as a speed hump. Speed humps or platforms are often painted or built using a different material to draw attention to the device.

Another form of this treatment is the use of coloured paint or brickwork at the point where the speed limit changes. This may involve painting the new speed limit on the road, or adding standard speed limit signs on the side of the road. Two examples of this treatment are shown below in Figure 2.16.

Figure 2.16: Surface treatments in the UK and USA

Source: Hallmark, Hawkins and Knickerbocker (2013).

When used at community entrances in rural Iowa (USA), Hallmark, Hawkins and Knickerbocker (2013) found a reduction in mean speed of up to 2.3 mph (3.7 km/h) and a reduction in 85th percentile speed of 2 mph (3.2 km/h), with the proportion of speeding drivers (> 5 mph (8 km/h) over limit) decreasing by 30–44%.

2.5.4 Pavement Marking Legends

Similar to surface treatments, pavement markings are intended to remind drivers of the speed limit or of an upcoming hazard or transition. Examples of this are 'SLOW' markings used in the USA and UK and painted speed limits on the road surface (Figure 2.17). Painted pavement signs can be more effective than conventional signs as these can be overlooked or obscured among other roadside infrastructure.

Figure 2.17: Two styles of pavement markings on rural roads in the USA

Source: Hallmark, Hawkins and Knickerbocker (2013).

These treatments have shown minimal speed reductions. Hallmark et al. (2007) found that 'SLOW' markings did not appear to have an effect on vehicle speeds, while McGee and Hanscom (2006) concluded that speed reductions of 6–7% were achieved with a reduction in overall speeding traffic.

In New South Wales, these pavement markings are used on local roads where there is a change in speeds limits, such as along approaches to rural villages or towns.

2.5.5 Raised Reflective Pavement Markers (RRPMs)

RRPMs are used in combination with line markings to improve delineation, especially at night and during adverse weather conditions. The reflective materials give drivers a longer sight distance of delineation. The devices also provide an audio-tactile warning when departing a lane.

Ermer, Fricker and Sinha (1991) found that after the installation of RRPMs on rural highways, the total number of crashes dropped by 4% and fatal crashes dropped by 17%. Gan, Shen and Rodriguez (2005) stated that RRPMs provided an estimated overall crash reduction of 10%, with 22 and 25% crash reductions at night and on wet roads, respectively.

2.5.6 Audio-tactile Line Markings

Audio-tactile line markings are painted edge or centre line markings that provide an audio-tactile stimulus to drivers if they cross the edge of their travel lane. Its intention is to warn fatigued, errant or inattentive drivers that they are leaving the roadway.

Audio-tactile line markings are most often used on the shoulder side of the road to help prevent run-off-road crashes, but can also be used in the centre of the road to warn vehicles that they are too close to potential oncoming traffic. It is common for audio-tactile edge lines to be installed when sealing shoulders on a rural road.

2.5.7 Chevron Alignment Markers

Chevron alignment markers (CAMs) are used to indicate the presence and severity of upcoming curves (Figure 2.18).

Figure 2.18: Chevron alignment markers on a rural curve

Source: ARRB Group.

CAMs can be installed with retro-reflective posts that enhance the sign's conspicuity and visibility. They improve the lateral positioning of vehicles, moving them away from centre of the carriageway, thereby reducing the likelihood of head-on crashes.

2.6 Roadside Barriers and Crash Cushions

A recent Austroads project, *Improving Roadside Safety* (Austroads 2014a), investigated the effects of a range of roadside hazards and treatment options on run-off-road casualty crash frequency and severity. This section draws on findings from the Stage 4 Interim report for that project.

A road safety barrier should be provided to protect vehicles from colliding with a hazard that could not otherwise be removed or relocated. The aim of a safety barrier or crash cushion is to lower the crash severity outcome in the event of a crash with the hazard. AASHTO (2009), also known as MASH-1, defines an effective safety barrier as being able to:

- contain and redirect the vehicle away from a roadside obstacle
- decelerate the vehicle to a safe stop
- break away readily, fracture or give way
- allow a controlled penetration
- be traversable.

The European Union Road Federation (2012) has stated that investment in road infrastructure 'can offer fast and cost-effective solutions that can reduce fatalities and related healthcare costs', in particular road restraint systems. In two case studies, it was presented that the installation of a semi-rigid median barrier could achieve a 65% reduction in casualty crashes, while the installation of a semi-rigid roadside barrier could achieve a 91% reduction. The European Union Road Federation also referred to the 2009 Annual Road Safety Report in France, which states that safety barriers 'can reduce fatalities up to a factor of four when compared to collisions against other roadside obstacles' (European Union Road Federation 2012).

2.6.1 Flexible Barriers

Flexible barriers or wire rope barriers are designed to transfer the kinetic energy of a collision into the lateral deflection of the barrier. In the event of a collision, the incident vehicle is given a longer period of time to decelerate, which is more likely to reduce the severity of the crash (Jacques et al. 2003). These barriers may also increase the injury risk to motorcyclists in the event of a crash (Jacques et al. 2003). There is a risk of errant motorcyclists being injured by the sharp wire ropes or posts in the event of a crash.

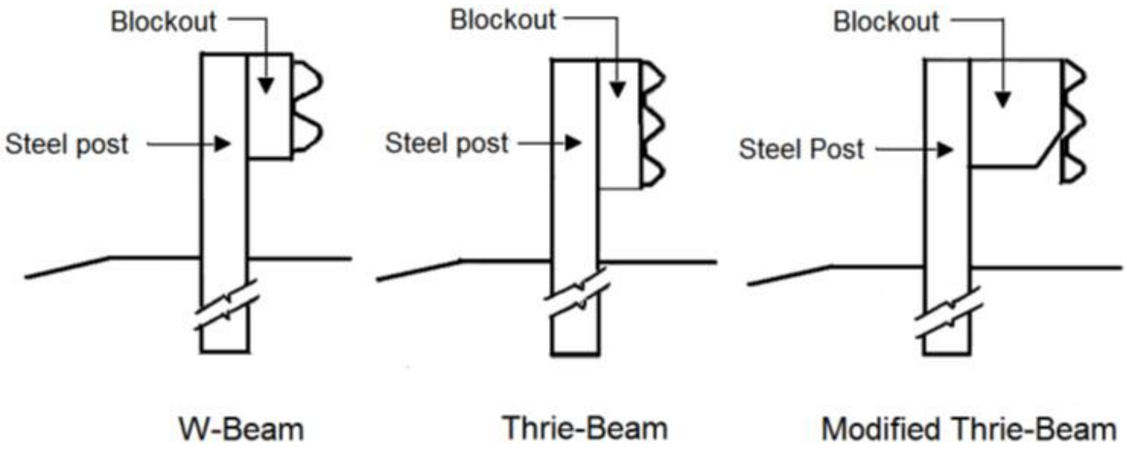
Barriers are advisable where the consequences of striking the barrier are lower than the consequences of striking a roadside object (Austroads 2010d). Flexible barrier designs have become more widely used than rigid designs, as they are able to gradually slow the vehicle after impact, reducing the likelihood of crashes caused by redirection or impact with the barrier itself.

Flexible barriers are also easier and quicker to repair and cause less damage to vehicles. One design drawback of flexible barriers is the need for greater deflection behind the barrier, i.e. a greater offset to the hazard they protect. This precludes flexible barriers from use in many situations, including on most locally-controlled urban roads where there is a constrained road corridor.

2.6.2 Semi-rigid Barriers

Semi-rigid barriers, such as steel guardrails, are designed to deform in the event of a vehicle impact and guide the vehicle in the direction of the traffic flow (Jacques et al. 2003). The level of deflection can vary with the use of wooden block-outs or by altering the beam design. It is also important to consider the transition to barriers, including providing barrier ends and installing an appropriate transition between different barrier types. An example of different semi-rigid barrier types is provided in Figure 2.19.

Figure 2.19: Examples of profiles of semi-rigid barriers



Source: Austroads (2010d).

2.6.3 Rigid Barriers

Rigid barriers are generally constructed of reinforced concrete and experience negligible deflection when impacted. As a general principle, when road space allows and guidelines are followed, it is considered best practice to use flexible barriers. However, rigid barriers are often required, especially in urban environments and where there are a high proportion of heavy vehicles. Rigid barriers are currently the most suitable barrier at containing errant heavy vehicles (Austroads 2010d).

Concrete barriers are the main types of rigid barriers used in Australia and New Zealand (Austroads 2010d). There are different types of concrete barriers and some examples of these are:

- New Jersey
- F-type
- vertical face
- single slope
- high containment.

2.6.4 Motorcyclist Barrier Solutions

When installing roadside or median barriers, it is important to consider the safety of all road users. Motorcyclists are particularly vulnerable to serious injuries when colliding with roadside objects, including rigid, semi-rigid and flexible barriers. Studies have shown that motorcyclists are over-represented in roadside barrier fatalities (Austroads 2014a).

Barriers are often closer to the road than other roadside objects, giving the rider less time to correct an error. During collisions, the vehicle may slide into the barrier elements (wires, rails or barrier posts) which can pose a significant hazard to motorcyclists.

Modifying roadside barriers is one of the solutions to reducing the injury and fatality risk for motorcyclists. Some of these solutions have been developed as retrofit devices, to save replacing entire lengths of barrier. Three common methods of modifying barriers to improve motorcycle crash outcomes include:

- shielding posts with additional beams or panels on the lower section of the semi-rigid or flexible barrier system to allow the rider to slide along the panel rather than impact posts
- replacing traditional I-beam posts in semi-rigid barriers with more forgiving sigma-shaped posts, or using weaker posts
- covering exposed posts with specifically designed impact attenuators.

A number of proprietary systems have been developed that fit into one of these categories, a range of which are presented in Austroads (2014a). It should be noted that the majority of these systems are unlikely to achieve the Safe System objective of reducing impacts to prevent fatal or serious injuries.

Aside from modifying barriers to improve motorcyclist safety outcomes, other options for improving motorcyclist safety include:

- wider roadside shoulders to provide more space for errant motorcyclists
- soft roadside vegetation which may be able to gradually decelerate errant motorcyclists
- plastic fences to absorb energy and slow the rider before striking the barrier
- smoothing the roadside and adding soft clay marbles to help decelerate the motorcycle before impacting the barrier, using a similar theory to the ‘gravel traps’ used at motor racing circuits.

2.6.5 Crash Cushions and Impact Attenuators

In addition to impact attenuators introduced in the previous section, there are a number of other solutions to preventing or lessening the impact into roadside objects such as poles, trees and barrier ends. This is especially applicable in urban settings where these rigid objects are often in close proximity to traffic lanes. It is not usually feasible to install continuous barriers along complete lengths of road in urban environments, but crash cushions and impact attenuators can be effective.

Short, single-hazard barriers can be used to shield trees and poles situated close to traffic, where it is not practical to move these objects (Figure 2.20).

Figure 2.20: Primus barrier system in Germany (see Section 1.5)

Source: European Union Road Federation (2009).

Systems such as this can be applied on rural roads where the traffic volume does not warrant continuous lengths of barrier, or on urban roads where frequent access points prevent standard barrier lengths (Austroads 2014a). These systems appear similar to semi-rigid barriers but perform more like a crash cushion with better impact absorption and a greater barrier deflection. The more flexible design means that maintenance costs may be higher than standard semi-rigid barriers.

When a roadside hazard cannot be removed, and there is significant risk of a head-on impact, impact attenuators or crash cushions can help to gradually decelerate the vehicle or redirect the vehicle in the case of side impacts (Austroads 2014a). Systems vary by their reusability; some require complete replacement after an impact, while others are able to retain a high percentage of their capacity without replacing parts. Systems also vary in the extent to which they redirect vehicles or capture impacts. Examples of different impact attenuators are shown in Figure 2.21.

Figure 2.21: Examples of crash cushions and impact attenuators (see Section 1.5)

a. Crash cushion. *b. Energy absorbing pole/tree buffer.* *c. RaptorTM utility pole and tree protector.*

Source: Austroads (2014a).

2.6.6 Frangible or Slip-base Poles

Infrastructure such as lighting poles and sign posts present a roadside hazard that can cause serious injuries to road users. The likelihood of serious injury can be reduced by replacing these objects with frangible or impact absorbing versions.

Frangible poles will deform and absorb vehicle impacts, but they have the capacity to remain standing and prevent secondary impacts. Different strength poles are available, with selection depending on the speed limit and the placement of the poles (i.e. in the median or roadside).

Slip-base poles are commonly used for street lighting poles and are designed to break away at the base when struck with a certain impact force. The impacting vehicle suffers relatively minor damage and vehicle occupants are at a lower risk of serious injury.

However, there are several problems associated with slip-base poles. They may rebound from the impact vehicle and then present a danger to pedestrians and other vehicles, they are susceptible to corrosion of the joints, need regular checks, are uni-directional, and may not perform as expected on embankments when cars strike higher up the pole (Austroads 2014a).

Countries in Europe now recommend frangible poles over slip-base poles, and in some cases require that all new poles are frangible on roads above a certain speed limit (e.g. 40 km/h).

Frangible sign posts are generally thinner than lighting poles as they have less mass to support. As a result they are more likely to break away on impact and therefore, care needs to be taken to ensure that poles and the attached signs do not cause secondary collisions.

Posts with longitudinal reinforcement may be more appropriate in urban locations where pedestrian safety is important (Austroads 2010e). Guidelines in many countries recommend particular posts for each road environment.

The use of flexible sign posts for low roadside signs such as chevron alignment markers and guide posts reduces the potential hazard of roadside objects, particularly for vulnerable road users such as motorcyclists.

A key design feature of flexible sign posts and guide posts is their ability to return to an upright position after a collision (Austroads 2010e). This reduces the need to replace impacted signs and guide posts and maintains the pre-crash level of safety as there is no gap from damaged or missing infrastructure.

Lattix posts are a particular proprietary product that is an innovative example of energy absorbing frangible posts, which may be beneficial in both urban and rural environments. An Australian demonstration crash test of a Lattix sign post was carried out in 2007. The damage caused to the test vehicle was relatively minor, with little crash energy likely to have been transferred to the vehicle and its occupants.

Innovative post designs such as this have application in both in urban and rural road environments.

2.7 Right-turning Treatments

A number of innovative and unconventional treatments are available for addressing safety and efficiency concerns related to right-turn phases at intersections. In many cases, these treatments are relatively expensive or require land acquisition, so may not be suitable for local government roads. Some treatments are likely to be relevant for to both state-controlled and local government roads. Further research may uncover low-cost versions of these treatments, or identify environments where versions of these treatments may be used.

2.7.1 Median U-turn

At intersections where there are a high proportion of crashes involving turning vehicles, it may be beneficial to ban right turns and require vehicles to travel straight through the intersection and perform a U-turn further along the road (Federal Highway Administration 2007). The driver can then turn left at the cross street. This treatment not only greatly reduces the incidence of crashes associated with turning manoeuvres but can improve efficiency on the major approach. In some cases, signal control may be needed at the U-turn median opening, particularly when there is a relatively high proportion of vehicles turning into the cross street.

Taylor, Lim and Lighthizer (2001) studied the effect of converting bi-directional median U-turns to directional median U-turns at urban intersections in Michigan (USA). Directional median U-turn designs give each direction of travel their own U-turn bay, reducing the likelihood of conflicts between turning vehicles. Injury crashes were between 3 and 71% lower, with an average injury reduction of 32%. Much of the change was attributable to the lower incidence of rear-end crashes due to the increased space for queuing vehicles. Where median U-turn treatments are installed, and where there is sufficient space, directional crossovers are preferable.

2.7.2 Guide Posts

Guide posts can be installed on the outside of curves to help improve delineation. These guide posts are fitted with small reflectors near the top to improve night-time effectiveness. Austroads (2012) estimates the crash reduction effectiveness of guide posts at 5%, although there have been examples of treatment sites where crashes actually rose, potentially due to drivers having more confidence in the vehicle path and increasing their speed (Elvik et al. 2009).

Modified guide posts have been trialled in Australia as a form of cost-effective delineation treatment (Macaulay et al. 2004). The guide posts started at 1 m in height, rising to 2 m at the centre of the curve, and back to 1 m at the end. They were also spaced at half the normal spacing, with the aim being to give the perception of a tighter curve than it was in reality. The treatment was considered a success at three of the six sites, with two sites showing no effect. The sites with poor existing delineation were more likely to have positive outcomes.

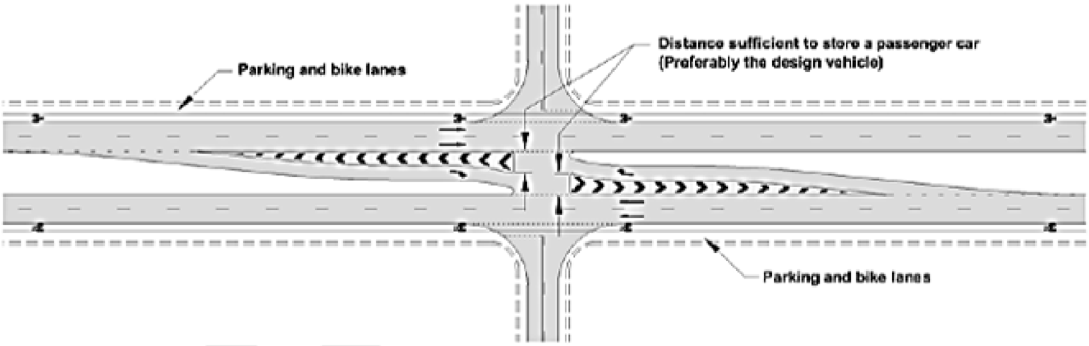
Figure 2.22: Modified guidepost curve treatment

Source: Macaulay et al. (2004).

2.7.3 Offset Right-turn Lanes

At intersections without dedicated right-turn phases, or at unsignalised intersections, vehicles waiting in opposing turn lanes can block sight lines for approaching through traffic. This can lead to crashes between right-turning and through vehicles. Designing an offset right-turn lane gives drivers a better view of approaching traffic, assisting drivers in determining appropriate gap selection. This treatment may be implemented at T- or cross-, urban or rural, and signalised or unsignalised intersections. An example design for offset right-turn lanes is shown in Figure 2.23.

Figure 2.23: Example of an offset right-turn treatment

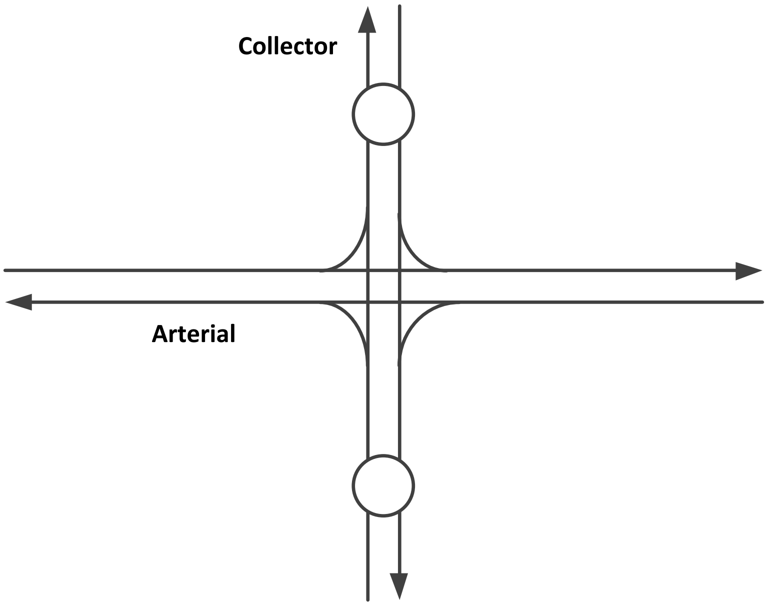


Source: Austroads (2010b).

2.7.4 Bowtie Intersection

A 'bowtie' intersection effectively removes all right-turn movements from an intersection. A vehicle intending to turn right from the arterial road must first turn left onto the side road and make a U-turn at a roundabout, before proceeding straight through the intersection. For vehicles on the side road, the driver would first travel through the intersection, before making a U-turn and then turning left onto the arterial road. An example of a bowtie intersection is shown in Figure 2.24.

Figure 2.24: Example of a bowtie intersection



Source: Arup (2004).

As with other intersection treatments, it is difficult to determine accurate crash reduction figures due to the large variability across sites. A report by Arup (2004) found that bowtie designs can have a number of safety benefits, including:

- reduced delay to through traffic
- increased intersection capacity
- no land purchase required on arterial road
- simplified pedestrian crossings
- fewer conflict points at the main intersection.

However, it was noted that bowtie intersections increased delay to right-turning traffic, required land acquisition on the side road, and some drivers chose to disregard the right-turn prohibition. Additionally, on roads where arterial traffic may wish to perform a U-turn, they would be required to utilise both roundabouts, significantly increasing travel distance and time. On roads where this is likely to be an issue, median breaks could be added at some point further along the arterial.

2.7.5 Painted Turning Lanes

There are often incidences of rear-end crashes with turning vehicles at intersections or significant driveways. Providing dedicated turning lanes can reduce this risk by allowing vehicles to safely decelerate away from the traffic lanes and not impact on any vehicles following them.

Kerbed turning lanes in a constructed verge or median are usually the ideal solution; however, this often requires more space and comes at a higher construction cost. Thus, for rural roads and urban roads with sufficient space, it may be preferable to install a painted turning lane.

A number of crash reduction figures are available for various painted turning lane treatments (Austroads 2012), including:

- 30% reduction for right-turn lanes (painted)
- 30% reduction for left-turn lanes (painted or constructed)
- 35% reduction for mid-block turning lanes (painted or constructed).

Painted turning lanes can also be incorporated into road diets, where through traffic lanes are removed to provide a two-way right-turn lane. Vehicles from either direction can use this lane to decelerate and wait to turn. It should also be easier to pick gaps in traffic with these turning lanes, as there will only be one lane of traffic to cross rather than two lanes.

2.7.6 Extended Right-turn Lanes

On roads with high traffic volume, or with a high proportion of turning vehicles, right-turn lanes can reach capacity and force vehicles to block the through traffic lanes. This can increase the crash risk as well as reduce the overall intersection capacity. Extending the right-turn lane allows more cars to queue away from through lanes, reducing the crash risk and improving the efficiency of the intersection.

2.7.7 Turn Restrictions

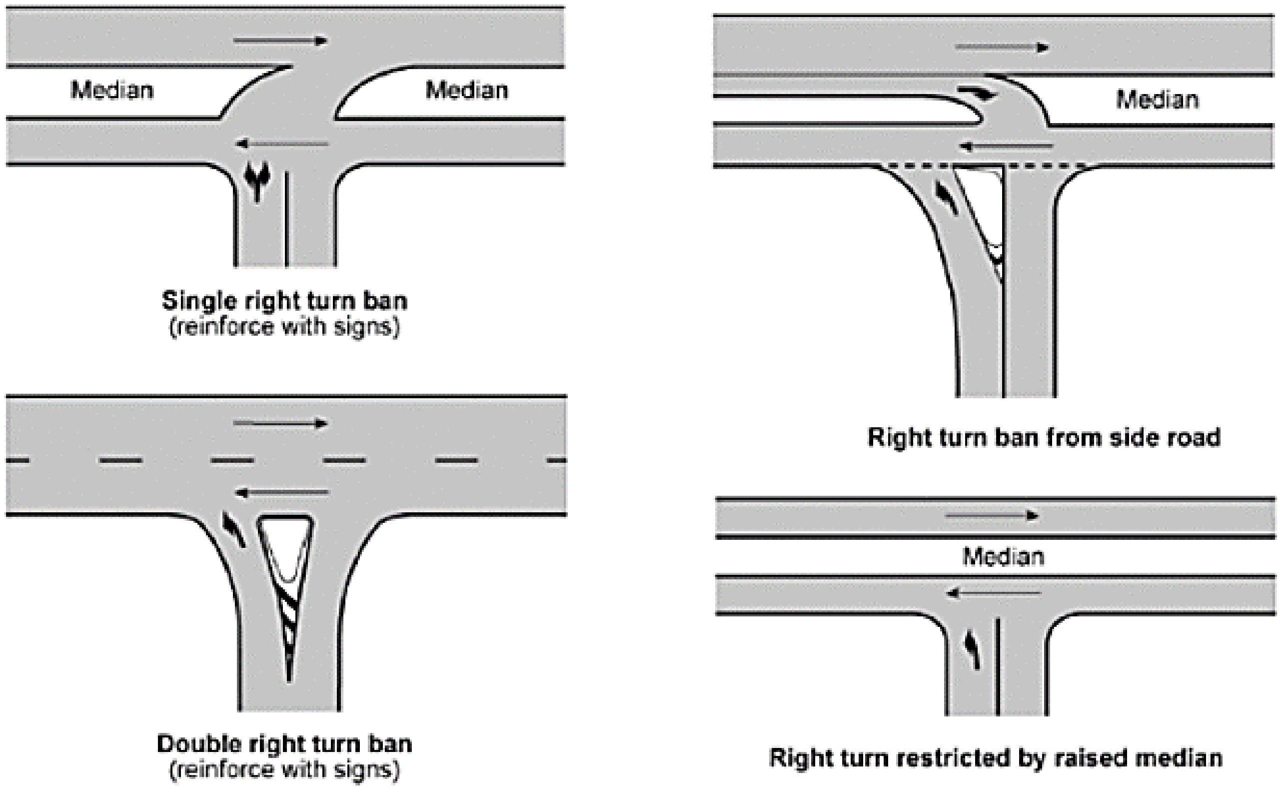
The Austroads *Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings* (Austroads 2013) provides guidance on traffic control devices and design elements that may be used to restrict turning movements. Turning movements may be restricted through signage and channelisation. Such treatments are generally not applicable for arterial intersections; however, may be beneficial for minor road intersections with arterials or other minor roads. Figure 2.25 illustrates channelisation options for restricting certain turning movements. Right-turning movements may also be banned through:

- closing medians through an intersection (preventing the right-turn movements)
- closing the minor street at an intersection
- installing a left-in/left-out splitter island (Figure 2.25)
- installing an island that effectively closes half of the minor street (permitting left-in only or permitting left-out only)
- signage.

Restricting turning movements may help improve:

- the safety at the intersection, as the number of conflict points is reduced
- the level-of-service for arterial roads where turning movements are restricted from and/or to a minor road.

Figure 2.25: Channelisation to ban right-turns



Source: Austroads (2013).

Austroads (2012) included a review of studies relating to regulatory signage that provided crash reductions associated with ‘right-turn bans, or U-turn and right-turn bans, with crash reductions ranging from 45–72%’. A crash reduction of 60% was recommended, although it was observed that the ‘actual crash reduction experienced will be dependent on the effect that diverted traffic has on nearby routes and intersections, and therefore consideration needs to be given to the potential for crash migration’.

In relation to median closures, Austroads (2012) recommended a crash reduction of:

- 55% for closing a median opening, where the opening had previously permitted turning movements in both directions
- 30% for restricting turning movements at a median opening from both to one direction (Figure 2.25).

An innovative low-cost treatment for median closures (full or partial) has been implemented successfully in several states in the USA, involving the use of flexible channeliser posts (American Traffic Safety Services Association 2011).

2.7.8 Mini-roundabouts

A mini-roundabout is a small roundabout with a solid painted circle or low traversable dome in the middle of the intersection. Mini-roundabouts were introduced to local roads in the UK in the 1970s at sites where there was inadequate space to install alternative measures of control such as a full roundabout or traffic signals. Mini-roundabouts are much cheaper as they only require paint or a different paving material to distinguish the central island, and can usually be installed with only relatively minor changes to the intersection geometry. While the right of way rules are the same for mini-roundabouts as for traditional roundabouts, there are often differences in the speed reduction performance of mini-roundabouts; hence, they are generally only used in lower speed environments.

The UK Department for Transport's *Mini-roundabouts: Good Practice Guidance* (Department of Transport 2007) notes that mini-roundabouts are installed:

- to improve the operation of an existing junction
- as an accident remedial measure
- as part of a traffic calming scheme
- to provide access to a new development.

The UK Department of Transport (2007) notes that crash rates for mini-roundabouts installed at three-leg intersections are similar to that for T-intersections, and approximately 30% less than for signalised sites. The severity of crashes (fatal and serious injury) is lower at three-leg mini-roundabouts than at signalised or T-intersections. The extent to which incidence and severity of crashes is reduced depends on site characteristics. A German study (Brilon 2011) found a 29% reduction associated with installation of mini-roundabouts at unsignalised intersections.

Hallmark et al. (2007) note the cost range for installation of a mini-roundabout is typically between $10 000 and $35 000.

The City of Monash has installed 35 mini-roundabouts between 2004 and 2010. The mini-roundabouts were installed in order to reduce the incidence of cross-traffic crashes (injury and non-injury crashes) where drivers had been failing to give way. Mini-roundabouts were selected due to constrained intersection geometry (i.e. the mini-roundabouts do not hinder truck movements through the intersections) and that they are a low-cost option (installations were funded through the council's capital works program).

Since installation of the mini-roundabouts, these intersections have experienced only one casualty crash compared to 20 casualty crashes in the five years prior to the installation of the mini-roundabouts.

Figure 2.26: Mini-roundabout installed in Monash City Council

Source: Monash City Council (n.d.).

2.8 Rural Gateway Treatments

Rural gateways are a speed reduction treatment used at the transition between a high speed rural road and a populated rural township or urban area. Treatments include the use of lighting, signage, wall and fence structures, lane narrowings, surface markings, median treatments, landscaping and vegetation to mark the transition between speed environments. The choice of specific treatments depends on jurisdictional guidelines, costs, road geometry and public amenity. Combinations of these treatments have been applied with various assessments conducted on the effectiveness in terms of speed and casualty crash reduction.

Following a study into the effectiveness of rural gateway treatments, Wheeler, Taylor and Payne (1993) concluded that gateways with visual impact, a central island, advance warning of traffic calming, and on wider roads, are effective in achieving reduced approach speeds.

Makwasha and Turner (2013) assessed the changes in crash frequency and severity attributable to the implementation of gateways in rural New Zealand (Figure 2.27). The study involved a before and after crash analysis at 102 treatment sites, and compared this to a control group of 62 sites. The results showed that gateways, particularly ‘pinch point’ gateways that effectively narrowed the lane width, were effective in lowering crashes at rural-urban transition zones in New Zealand.

Figure 2.27: Example rural gateway treatments

a. Example sign only gateway treatment.
Source: Makwasha and Turner (2013).

b. Example pinch point gateway treatment.

Krammes and Sheldahl (2009) describe a coloured speed limit pavement treatment installed on the entrance to a rural US community (Figure 2.28). The treatment also included a wide edge line adjacent to the coloured pavement 'to enhance visibility'. The treatment was found to be effective in reducing 85th percentile speeds, particularly where speeds were considerably higher than the posted speed limit. The treatment was noted to be associated with a 0–9 mph (0–14 km/h) reduction in 85th percentile speeds.

Figure 2.28: Coloured speed limit pavement treatment

Source: Krammes and Sheldahl (2009).

2.9 Innovative Cost-effective Treatments

A number of innovative treatment options were identified and are described below:

- Glow in the dark road markings:
  - These road markings were developed in the Netherlands and are currently under trial along a 500 m stretch of road on the N329 in Oss, approximately 100 km south east of Amsterdam (Figure 2.29).
  - The photoluminescence compound in the road markings absorbs light during the day and glows at night for approximately eight hours. These road markings could eliminate the need for street lighting, thereby saving energy costs and providing valuable environmental benefits (BBC 2014, Woodford 2016).

Figure 2.29: Glow in the dark road markings along the N329 in Oss, Netherlands

Source: BBC (2014).

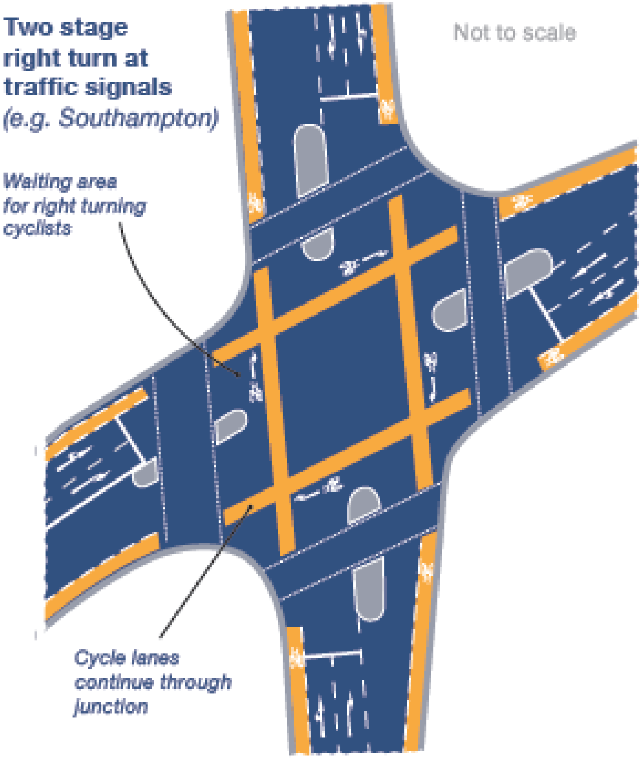
- Safe hit median posts:
  - Safe hit plastic posts (Figure 2.30) installed at 5 m intervals along a flushed road median in New Zealand were effective in reducing speed, improving lane positioning, driver behaviour and safer merging (Mackie, Marsh & Pilgrim 2011).

Figure 2.30: Use of safe hit median posts in New Zealand

Source: Mackie, Marsh and Pilgrim (2011).

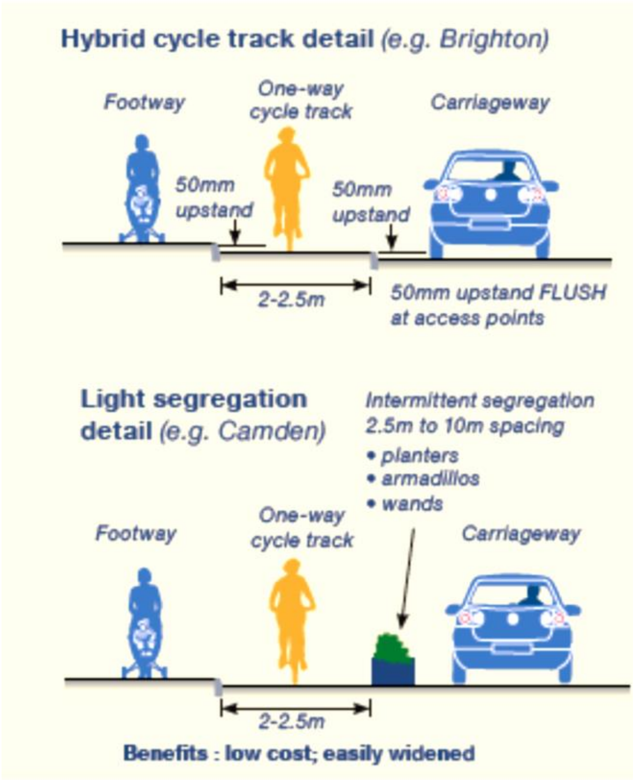
- Two-stage right-turns for cyclists:
  - Sustrans in the UK have developed a design guideline to assist road practitioners to design and implement safe cycle facilities in their jurisdictions. The guideline includes innovative cycle facilities.
  - The two-stage right-turn for cyclists facility allows cyclists to turn right at busy signalised intersections in two stages (Figure 2.31) and includes a safe waiting area where cyclists may wait safely away from oncoming traffic and turn right when it is safe (Sustrans 2014).
- Hybrid cycle track:
  - A segregated cycle facility which consists of a footpath, 2–2.5 m cycleway and roadway, with each facility clearly segregated by 50 mm (Sustrans 2014).

Figure 2.31: Diagrammatic example of a two-stage right turn for cyclists



Source: Sustrans (2014).

Figure 2.32: Proposed layout of hybrid cycle track in the UK



Source: Sustrans (2014).

- Cycleway segregation using planters, wands and armadillos:
  - A segregated cycle facility which consists of a 2–2.5 m cycleway and road, where the facilities are segregated by using planters, wands or armadillos (Sustrans 2014).
- Optical speed bars:
  - Research evaluated the effectiveness of using cost-effective speed reduction measures such as optical speed bars on rural undivided two-lane approaches to rural communities. These bars create the perception to drivers that they are travelling at a higher speed, thereby encouraging them to reduce their approach speeds.
  - A before and after study revealed that the mean and 85th percentile speeds along these roads had reduced. It concluded that optical speed bars are a practical and economical treatment option to encourage lower approach speeds towards rural communities (Balde & Dissanayake 2013).

Figure 2.33: Example of optical speed bars in Virginia, USA

Source: Federal Highway Administration (2014).

- Parallelogram-shaped pavement markings:
  - A study evaluated the effects of parallelogram-shaped road markings on vehicle speeds and speed violations in the vicinity of pedestrian crossings on urban roadways in China. Similar to optical bars, these road markings create the perception to drivers that they are travelling at a higher speed, thereby encouraging them to reduce their approach speed.
  - The results showed that the parallelogram-shaped pavement markings had reduced vehicle speeds and speed violations in the vicinity of pedestrian crossings (Guo et al. 2014).
  - These road markings are practical and cost-effective treatment measures to reduce speeds and improve pedestrian safety.

Figure 2.34: Example of a site treated with parallelogram-shaped road markings

Source: Guo et al. (2014).

2.10 Assessment of Cost-effective Measures on Local Government Roads

This project seeks to identify and assess suitable cost-effective treatment measures that improve safety on local roads. Sites will be chosen in consultation with the project steering group. The aim of this task will be to assess and recommend measures that could help each treatment site be better aligned with Safe System principles.

2.10.1 Defining Cost-effective Treatments

The challenge is to develop a common definition of cost-effective treatments that will be applicable to all local governments in Australia and New Zealand. Incorporating each aspect of the Safe System pillars, cost-effective measures may include:

- engineering measures including improvements to delineation (at curves and junctions), review of speed limits, signs, road markings, hazard removal and vegetation clearance
- enforcement measures targeting speed, impairment and seat belts
- education programs targeting driver speed, distraction and inattention, medical conditions, etc.

Higher cost options may include removal of roadside hazards or protection through installation of barriers, installation of pedestrian facilities, provision of road shoulders, improvements to road alignment or intersection layout, and sealing of shoulders.

At the project stakeholder consultation workshop conducted in 2012, the costs of road safety treatment measures were defined as:

- projects with capital costs < $50 000 = low cost ($)
- projects with capital costs between $50 000 and $250 000 = medium cost ($$)
- projects with capital costs > $250 000 = high cost ($$$).

While these costs relate to capital costs, the whole-of-life costs should also be considered.

2.10.2 Treatment Options Summary Tables

Safe System treatment options summary tables were prepared to provide a useful reference for practitioners in selecting suitable treatment options to address specific road safety issues along local roads. Table 2.3 illustrates an example of this table.

The complete list of tables is presented in Appendix A.

Table 2.3: Safe System summary treatment options for reducing speeds at intersections

Treatment		Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Primary	Installing roundabout	Speed reduction/ crash severity	Urban/rural	$$$	✓	✓			
Supporting	Speed cameras	Enforcement	Urban/rural	$$	✓	✓			
	Intersection raised platforms	Speed reduction	Urban	$$	✓	✓			
	Turn to red if speeding	Enforcement/ speed reduction	Urban/rural	$	✓	✓			✓
	Rest-on-red	Separation/ speed reduction	Urban	$	✓	✓			✓
	Transverse rumble strips	Speed reduction	Urban/rural	$	✓	✓	✓		✓
	Restriction of sight distance	Speed reduction	Urban/rural	$	✓	✓			✓
	Decrease in speed limit unrestricted to a speed limit 100–80 km/h 80–60 km/h 60–50 km/h	Speed reduction	Urban/rural	$	✓	✓	✓		

Source: ARRB Group.

Treatment options in the tables are ordered from primary to supporting Safe System treatments.

Primary treatments satisfy Safe System principles and are able to eliminate FSI crashes. These treatments are considered to be best practice and should be considered first.

Supporting treatment options are measures that provide incremental benefits towards achieving a Safe System. These treatments may not eliminate FSI crashes but are able to reduce risk. From a cost perspective, primary treatments are considered to be medium to high costs, while supporting treatments are less expensive and are regarded to be more cost-effective treatment options.

A majority of the treatment options described in the tables are supporting treatments as these treatments are deemed to be practical, easily implemented, cost-effective and more applicable to local governments. Guidance is provided in the summary tables indicating how each treatment option satisfies the four pillars of the Safe System approach.

Adopting an area-wide rather than a site-specific approach is likely to result in greater success. When considering an appropriate treatment, or package of treatments, there is a need to understand the nature and extent of the road safety problem on local roads, tailoring the treatments to the road environment, as well as having an awareness of the different road users at a local government level.

2.11 Conclusion

The literature review analysed a range of reported Australian and international research on various types of road infrastructure-based safety treatment options. Treatment options were classified as being either primary or supporting Safe System treatment options, depending on their effectiveness to address FSI crashes.

Primary treatments are defined as best practice and satisfy Safe System principles. These treatments have the potential to deliver near zero FSI crashes. Supporting treatments are measures that provide incremental benefits towards achieving a Safe System. From a cost perspective, primary treatments are generally medium to high cost, while supporting treatments are generally regarded to be cost-effective treatment options.

From cost-effectiveness, practicality and an ease of implementation viewpoint, supporting treatments are the most readily accessible options to be considered by local governments and application will provide an incremental movement towards achieving a Safe System on their road networks. However, primary treatments should be considered in the context of the road environment and given priority to address the crash problem in order to achieve real Safe System outcomes.

3. The Road Safety Performance of Local Government-Managed Roads

3.1 Purpose, Scope and Limitations of Crash Data and Analysis

Crash data for local roads across Australia and New Zealand were analysed to gain an understanding of the type of safety issues that exist and the type of locations that should be considered a priority for action. The analysis and conclusions drawn from a review of the crash data is discussed in this section of the report.

In brief, the analysis undertaken for this project sought to provide a level of benchmarking of crashes on local roads, which involved the following:

- A review of the latest five years of crash data (2006–10) to identify dominant factors reported as contributing to crash causation and FSI outcomes.
- A review of the latest 10 years of crash data (2001–10) to determine the change over the longer-term of crashes on local roads.
- A comparison of crashes between local rural and urban road environments, looking at crash rates, dominant types of crashes, and road and road environment features.

The most recent five years of crash data available for each jurisdiction was used for the analysis (2006–10), except for the analysis by year, where 10 years of data was used (2001–10) to allow a comparison over a longer period.

The analysis was not able to include data from a number of jurisdictions:

- Tasmanian data was not included in the analysis, as its database does not include a variable to differentiate between urban and rural crashes.
- The Northern Territory database does not include a variable that distinguishes whether a road was managed by state or local government.
- ACT data was not included in the analysis as variables to distinguish between urban and rural, and between state- and local government-controlled roads, were not available.

The Western Australian data set had a large number of crashes that were assigned to property damage only (PDO) which included category ‘inj: no medical attention’.

Crashes in New South Wales and South Australia at intersections on 80 km/h roads in mainly built-up areas were allocated to the ‘unknown’ road environment type, as information on whether these were on divided or undivided roads was unavailable. However, these only form a very small proportion of crashes (3% of casualty crashes on state-managed roads, and less than 2% of FSI crashes on state- and locally-managed roads in both NSW and SA), and omission of these crashes has little impact on the general trends.

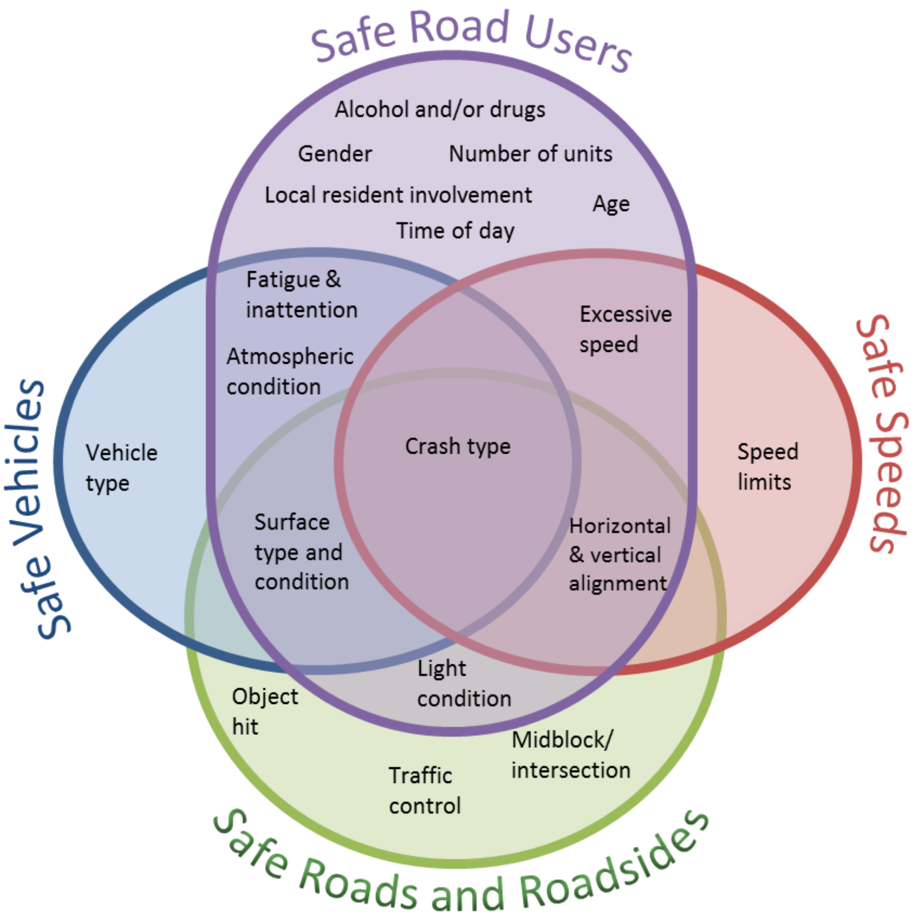
The categories employed by jurisdictions to describe crash characteristics vary. In some cases, categories have been collapsed to create categories that better correspond with those employed in other jurisdictions, and also for simplicity. The analysis in this report only includes crashes (and associated casualties) where the crash severity outcome was fatal, admitted to hospital, or medical treatment (i.e. excludes PDO crashes).

3.2 Crash Characteristics

The crash data analysis aims to identify key crash types for urban and rural road environments.

Key relationships between different crash data analysis factors and Safe System elements are illustrated in Figure 3.1. It is noted that many of the factors can be related to all elements of the Safe System, however, this diagram intends to illustrate the key relationships.

Figure 3.1: Crash data factors key relationship to Safe System elements



Source: ARRB Group.

Analysis of the characteristics associated with crashes on local government roads is presented in the following sections.

3.2.1 Severity

Table 3.1 and Figure 3.2 show that a large proportion of FSI crashes occur on the local road network (46% in Australia and 63% in New Zealand). Over half of FSI crashes occurred on the local road network in Queensland, Western Australia and New Zealand; while in Victoria and South Australia, less than 40% occurred on the local road network.

In Australia, 35% of FSI crashes occur on local government-managed roads in urban road environments, while 8% of FSI crashes occur on local government-managed roads in rural road environments.

In New Zealand, 41% of FSI crashes occur on local government-managed roads in urban road environments, while 22% of FSI crashes occur on local government-managed roads in rural road environments.

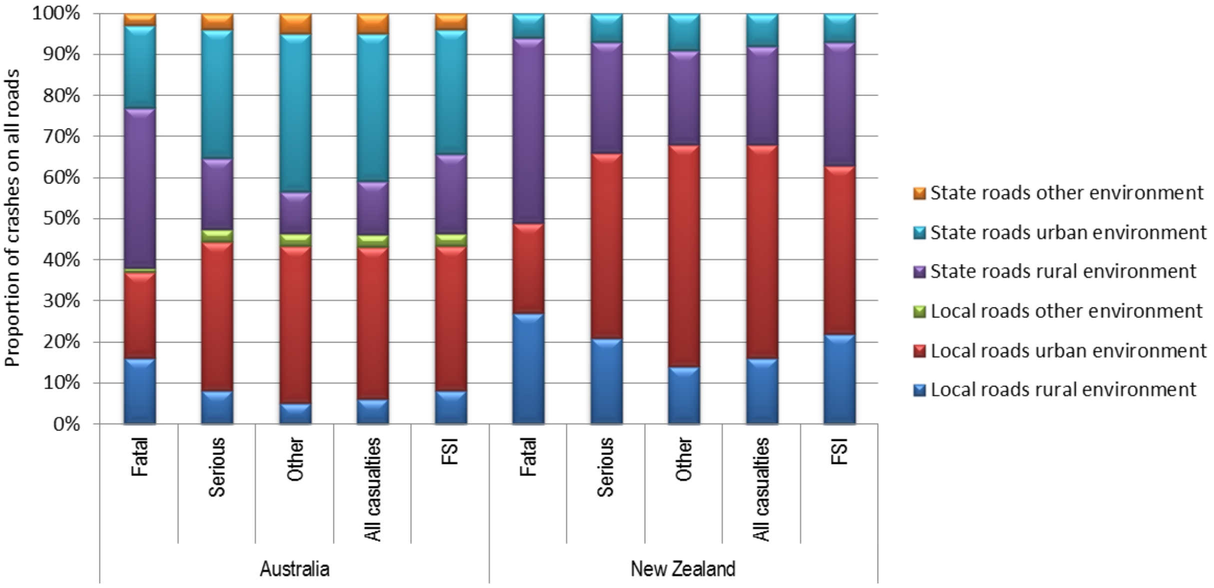
Table 3.1: Crash severity by local- vs state-managed and rural vs urban roads (2006–10)[1] – proportions by severity category

Jurisdiction	Crash severity	Local-managed roads			State-managed roads			Total all roads (%)	% on local-managed roads
		Rural road (%)	Urban road (%)	Other/ unknown (%)	Rural road (%)	Urban road (%)	Other/ unknown (%)		
NSW	Fatal	14	20	1	38	23	3	100	35
	Serious[2]	8	36	1	17	34	4	100	45
	Other[2]	5	41	0	10	41	3	100	46
	All casualties	6	39	1	12	40	3	100	45
	Fatal + SI	9	34	1	19	33	4	100	44
Victoria	Fatal	16	13	0	39	29	3	100	29
	Serious	8	26	2	16	43	3	100	36
	Other	5	27	2	11	47	4	100	35
	All casualties	7	27	2	13	45	4	100	35
	Fatal + SI	8	26	2	17	42	3	100	36
Queensland	Fatal	15	28	0	41	13	3	100	43
	Serious	7	48	0	20	22	4	100	55
	Other	5	51	0	14	26	4	100	55
	All casualties	6	49	0	17	24	4	100	55
	Fatal + SI	7	47	0	21	21	4	100	54
Western Australia	Fatal	19	27	2	36	11	4	100	47
	Serious	7	38	16	11	16	11	100	61
	Other	3	38	17	5	21	15	100	59
	All casualties	5	38	16	7	20	13	100	59
	Fatal + SI	8	37	14	13	15	10	100	60
South Australia	Fatal	18	12	0	41	27	3	100	30
	Serious	12	27	0	24	35	2	100	39
	Other	5	30	1	9	53	3	100	36
	All casualties	6	29	1	12	49	3	100	36
	Fatal + SI	13	25	0	25	34	2	100	38
Australia	Fatal	16	21	1	39	20	3	100	37
	Serious	8	36	3	17	31	4	100	47
	Other	5	38	3	10	38	5	100	46
	All casualties	6	37	3	13	36	5	100	46
	Fatal + SI	8	35	3	19	30	4	100	46
New Zealand	Fatal	27	22		45	6		100	49
	Serious	21	45		27	7		100	66
	Other	14	54		23	9		100	68
	All casualties	16	52		24	8		100	68
	Fatal + SI	22	41		30	7		100	63

1 *Crashes where rural/urban or local/state-controlled were unknown have been excluded.*
2 *NSW does not separate injury crashes by 'serious' or 'other' injury. Conversion factors are applied to estimate serious and minor injury crashes.*

Source: ARRB Group.

Figure 3.2: Proportion of crash severity on local- and state-managed roads (2006–10)



Source: ARRB Group.

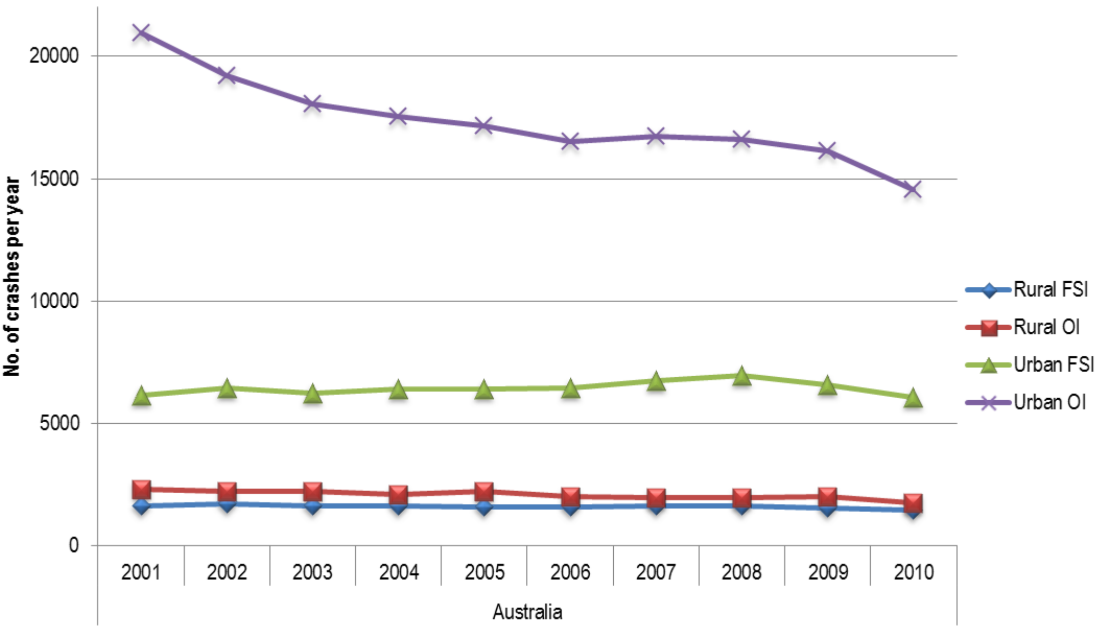
3.2.2 Year

The number of FSI and other injuries for local government-managed roads in Australia for the 10-year period of 2001–10 is presented in Figure 3.3.

The results show that the number of casualty crashes and the crashes resulting in FSI on rural roads has not changed significantly over the 10-year period. On urban roads, the number of casualty crashes resulting in FSI has fluctuated over the 10-year period without a net significant change. However, there is continued reduction in the number of other injuries on urban roads during this period.

It should be noted that the number of vehicles on both rural and urban roads has increased over the 10 years.

Figure 3.3: Casualty crashes by year (2001–10) – Australia LG-managed roads

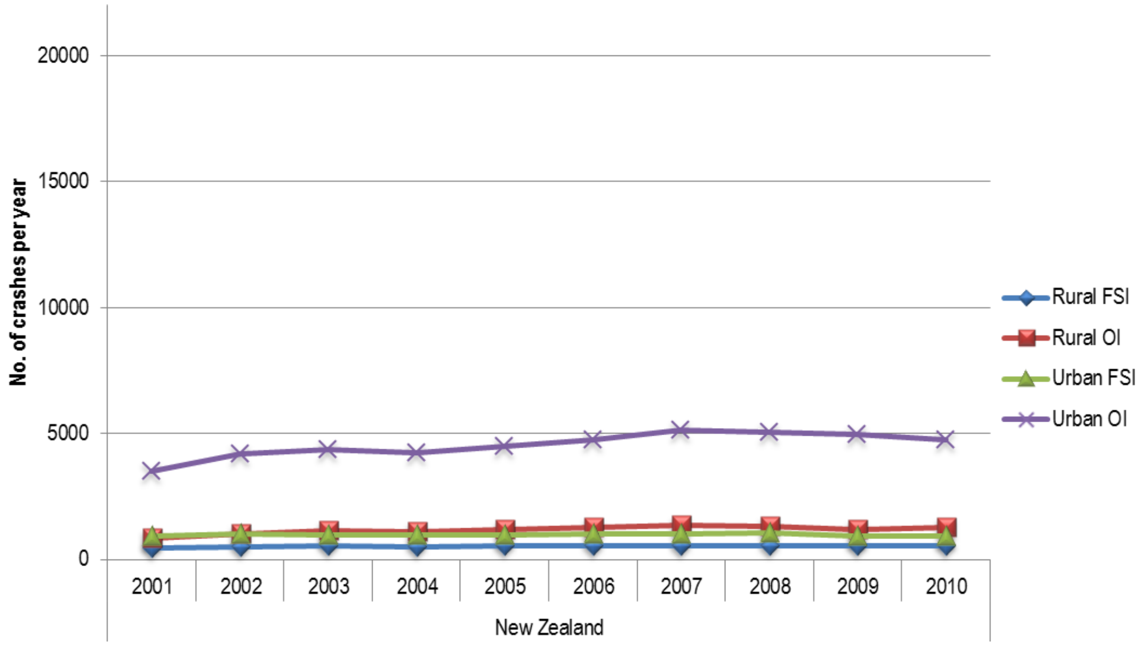


Source: ARRB Group.

Figure 3.4 presents the results for the number of casualty crashes on local government-managed roads in New Zealand for the 10-year period 2001–10. The results show that the number of crashes resulting in FSI on both rural and urban roads has not changed significantly over the 10-year period.

However, there appears to be a net increase in other injuries on urban roads over this period. It is observed that a reduction trend started in 2007 and continued to 2010.

Figure 3.4: Casualty crashes by year (2001–10) – New Zealand LG-managed roads



Source: ARRB Group.

3.2.3 Crash Type

Table 3.2 shows the total number of injury crashes associated with each crash type and the percentage of these crashes resulting in FSI for each crash type. These results are also presented in Figure 3.5.

The results show that in Australia and New Zealand in both the rural and urban environments, the crash type that results in the highest percentage of FSI is 'pedestrian' crash type. The crash type 'other', which has the highest percentage of FSI crashes in New Zealand urban environment, has not been considered.

In the rural environment in both Australia and New Zealand, the number of injury crashes for the pedestrian crash type is lower than most of the other crash types. However, due to the vulnerable nature of pedestrians, a higher percentage of this type of crash results in an FSI.

When not considering the crash type 'other', the second highest percentage of FSI crashes in rural environments for both Australia and New Zealand results from the 'opposing direction' crash type, with 57% in Australia and 39.7% in New Zealand.

In the urban environment in both countries, 'off path on straight', 'overtaking' and 'off path on bend' all have a similar percentage of injury crashes resulting in FSI. In Australia, these are 37.8%, 36.2% and 35.9%, respectively; and in New Zealand, they are 20.4%, 18.8% and 20.9%, respectively.

When comparing the total number of injury crashes associated with a crash type, 'off path on bend' has the highest number of injury crashes in the rural environment, with 6502 crashes in Australia and 4349 crashes in New Zealand for the analysis period 2006 to 2010.

In the urban environment, ‘same direction’ and ‘intersection’ crash types are the highest contributors to injury crashes in both Australia and New Zealand. The number of injury crashes for the analysis period of 2006 to 2010 in Australia is 23 299 for ‘same direction’ and 22 459 for ‘intersection’; and in New Zealand, 5259 for ‘same direction’ and 5509 for ‘intersection’.

Overall, the proportion of crashes resulting in FSI is higher for all crash types in the rural environment than in the urban environment. In Australia, it ranges from 30.4% for ‘same direction’ to 74.5% for ‘pedestrian’. In New Zealand, the range is 18.3% for ‘same direction’ to 54.3% for ‘pedestrian’. This is due to the presence of higher speed limits in rural environments than in urban environments.

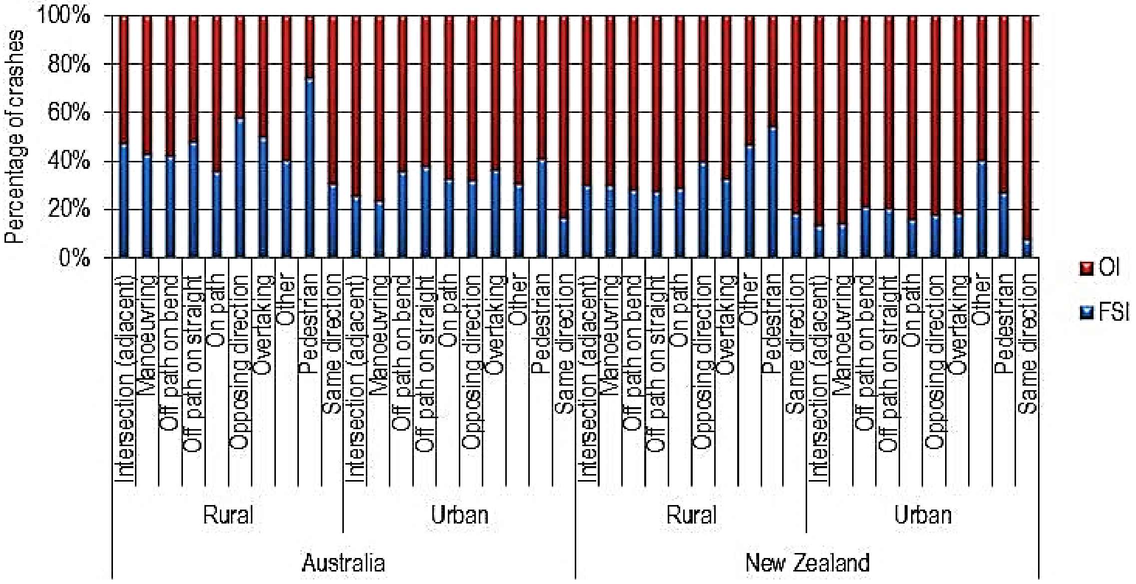
Table 3.2: Casualty crashes by crash type (2006–10) LG-managed roads

Country	Area	Crash type	Injury type		Total (%)
			FSI (%)	OI (%)	
Australia	Rural	Intersection (adjacent)	454 (47.4)	504 (52.6)	958 (100)
		Manoeuvring	122 (42.6)	165 (57.4)	287 (100)
		Off path on bend	2 761 (42.5)	3 741 (57.5)	6 502 (100)
		Off path on straight	2 503 (48.2)	691 (51.8)	5 194 (100)
		On path	380 (35.9)	679 (64.1)	1 059 (100)
		Opposing direction	790 (57.8)	575 (42.2)	1 365 (100)
		Overtaking	139 (50)	140 (50)	279 (100)
		Other	283 (40.3)	419 (59.7)	702 (100)
		Pedestrian	120 (74.5)	41 (25.5)	161 (100)
		Same direction	322 (30.4)	737 (69.6)	1 059 (100)
	Urban	Intersection (adjacent)	5 726 (25.5)	16 733 (74.5)	22 459 (100)
		Manoeuvring	2 072 (23.8)	6 625 (76.2)	8 697 (100)
		Off path on bend	3 426 (35.9)	6 117 (64.1)	9 543 (100)
		Off path on straight	5 735 (37.8)	9 448 (62.2)	15 183 (100)
		On path	1 400 (32.4)	2 927 (67.6)	4 327 (100)
		Opposing direction	4 343 (31.9)	9 288 (68.1)	13 631 (100)
		Overtaking	305 (36.2)	536 (63.8)	841 (100)
		Other	594 (30.9)	1 327 (69.1)	1 921 (100)
		Pedestrian	5 428 (41.1)	7 767 (58.9)	13 195 (100)
		Same direction	3 827 (16.4)	19 472 (83.6)	23 299 (100)
New Zealand	Rural	Intersection (adjacent)	179 (30.4)	410 (69.6)	589 (100)
		Manoeuvring	54 (30.3)	124 (69.7)	178 (100)
		Off path on bend	1 225 (28.2)	3 124 (71.8)	4 349 (100)
		Off path on straight	403 (27.7)	1 053 (72.3)	1 456 (100)
		On path	69 (28.8)	171 (71.3)	240 (100)
		Opposing direction	470 (39.7)	714 (60.3)	1 184 (100)
		Overtaking	84 (32.4)	175 (67.6)	259 (100)
		Other	46 (46.5)	53 (53.5)	99 (100)
		Pedestrian	57 (54.3)	48 (45.7)	105 (100)
		Same direction	115 (18.3)	512 (81.7)	627 (100)

Country	Area	Crash type	Injury type		Total (%)
			FSI (%)	OI (%)	
New Zealand (cont.)	Urban	Intersection (adjacent)	733 (13.3)	4 776 (86.7)	5 509 (100)
		Manoeuvring	286 (14.2)	1 728 (85.8)	2 014 (100)
		Off path on bend	847 (20.9)	3 197 (79.1)	4 044 (100)
		Off path on straight	471 (20.4)	1 837 (79.6)	2 308 (100)
		On path	219 (15.7)	1 173 (84.3)	1 392 (100)
		Opposing direction	779 (18)	3 544 (82)	4 323 (100)
		Overtaking	130 (18.8)	562 (81.2)	692 (100)
		Other	94 (40.5)	138 (59.5)	232 (100)
		Pedestrian	1 040 (26.8)	2 841 (73.2)	3 881 (100)
		Same direction	407 (7.7)	4 852 (92.3)	5 259 (100)

Source: ARRB Group.

Figure 3.5: Casualty crashes by crash type (2006–10) LG-managed roads



Source: ARRB Group.

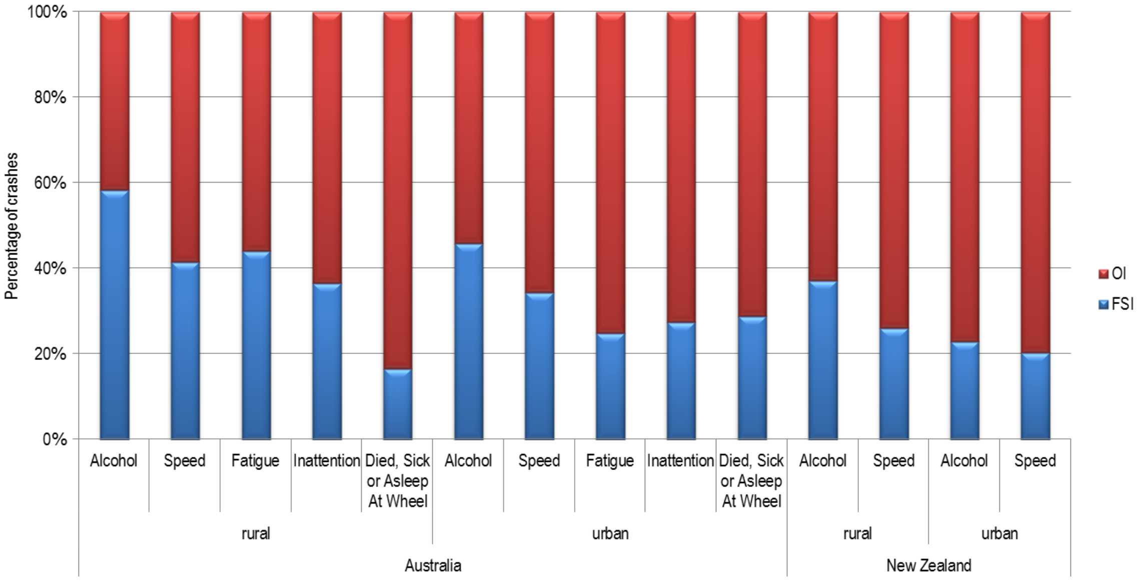
3.2.4 Road User Contributing Factors

Alcohol is the highest road user contributing factor to the percentage of casualty crashes resulting in FSI on both Australian and New Zealand rural and urban local government roads, as shown in Figure 3.6, with the highest percentage of almost 60% occurring in the rural road environment in Australia.

In Australia, there was a higher proportion of FSI crashes associated with speed, fatigue and inattention on rural roads than on urban roads.

New Zealand only records alcohol and speed. This also shows a similar trend to Australia, where a higher percentage of FSI crashes is attributed to speed on rural roads than on urban roads.

Figure 3.6: Casualty crashes by road user contributing factors (2006–10) LG-managed roads



Source: ARRB Group.

3.2.5 Mid-block/Intersection

In both Australia and New Zealand, ‘cross intersection’ casualty crashes in the rural environment result in a higher percentage of FSI than at any other location in that environment, with 47.8% in Australia and 32.6% in New Zealand, as shown in Table 3.3 and represented in Figure 3.7. The second highest percentage of FSI crashes on rural roads occurs at ‘not at intersection’ (mid-block), with 44.8% in Australia and 30.3% in New Zealand.

These results show the severity of ‘cross intersection’ type crashes, where the total number of injury crashes in Australia is 739 resulting in 353 FSI, compared to ‘not at intersection’ with 15 214 injury crashes resulting in 6821 FSI. The number of injury crashes and FSI for the ‘not at intersection’ crash type is considerably higher; however, the percentage resulting in FSI is lower than for ‘cross intersection’. A similar result is shown for New Zealand.

In the urban environment in both Australia and New Zealand, casualty crashes ‘not at intersection’ result in a higher percentage of FSI than ‘cross intersection’ and ‘T-intersection’ type crashes, with 31.7% in Australia and 19.1% in New Zealand. This crash type is also the highest contributor to injury crashes, with a total of 52 773 injury crashes in Australia and 14 267 in New Zealand.

The second highest percentage of injury crashes resulting in FSI in the urban environment occurs at ‘T-intersection’, with 27.7% in Australia and 15.2% in New Zealand. The number of injury crashes for this crash type is 29 591 in Australia and 7874 in New Zealand. The number of injuries for this crash type is almost half of that for ‘not at intersection’; however, the percentage resulting in FSI is only slightly lower for ‘T-intersection’ than ’not at intersection’.

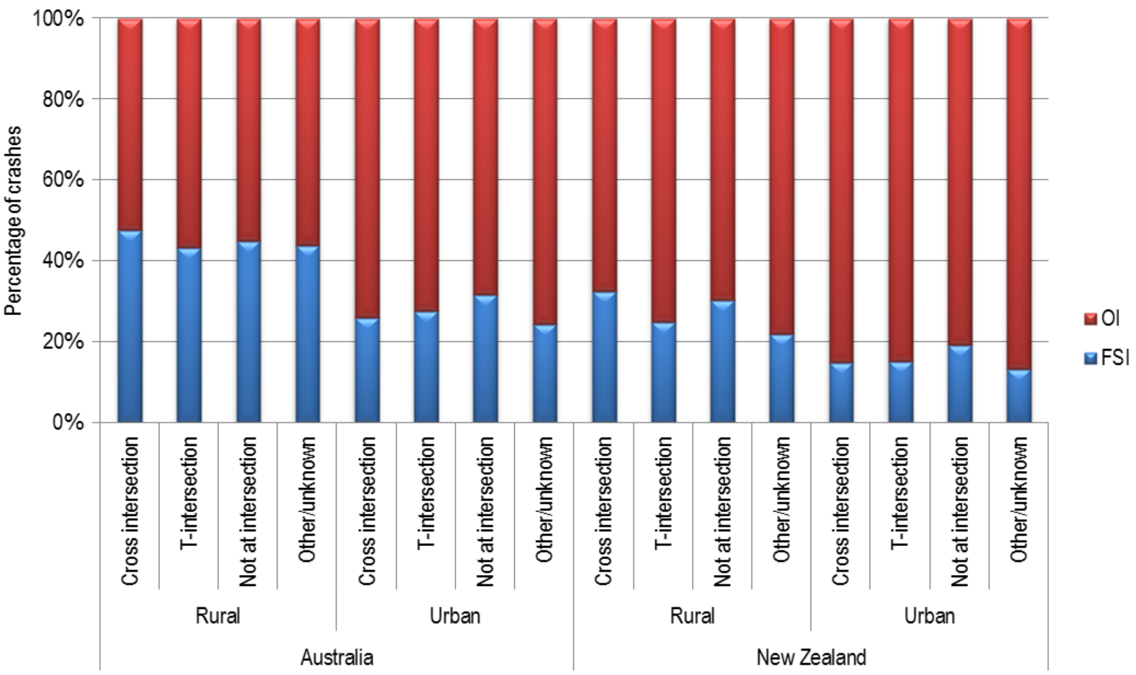
These results show that even though the percentage of FSI crashes for ‘not at intersection’ is higher than for ‘T-intersection’, due to the total number of crashes and the minor difference in the percentage of FSI, crashes for ‘T-intersection’ are likely to be more severe than ‘not at intersection’ in the urban environment.

Table 3.3: Casualty crashes by location (2006–10) LG-managed roads

Country	Area	Location	Injury type		Total (%)
			FSI (%)	OI (%)	
Australia	Rural	Cross intersection	353 (47.8)	386 (52.2)	739 (100)
		T-intersection	603 (43.3)	788 (56.7)	1 391 (100)
		Not at intersection	6 821 (44.8)	8 393 (55.2)	15 214 (100)
		Other/unknown	98 (44)	124 (56)	222 (100)
	Urban	Cross intersection	6 168 (25.9)	17 600 (74.1)	23 768 (100)
		T-intersection	8 183 (27.7)	21 408 (72.3)	29 591 (100)
		Not at intersection	16 738 (31.7)	36 035 (68.3)	52 773 (100)
		Other/unknown	1 768 (24.2)	5 524 (75.8)	7 292 (100)
New Zealand	Rural	Cross intersection	157 (32.6)	325 (67.4)	482 (100)
		T-intersection	212 (24.9)	638 (75.1)	850 (100)
		Not at intersection	2 285 (30.3)	5 251 (69.7)	7 536 (100)
		Other/unknown	48 (22)	170 (78)	218 (100)
	Urban	Cross intersection	769 (14.8)	4 423 (85.2)	5 192 (100)
		T-intersection	1 198 (15.2)	6 676 (84.8)	7 874 (100)
		Not at intersection	2 730 (19.1)	11 537 (80.9)	14 267 (100)
		Other/unknown	309 (13.3)	2 012 (86.7)	2 321 (100)

Source: ARRB Group.

Figure 3.7: Casualty crashes by location (2006–10) LG-managed roads



Source: ARRB Group.

3.2.6 Speed Limit

Speed limits can provide an indication of the function of the road, e.g. lower speed limit roads are generally lower on the road hierarchy. It should be noted that the speed limit analysis reflects the definitions adopted for urban and rural road environments, i.e. urban road environments generally include roads with lower speed limits, while rural road environments feature roads with higher speed limits.

The results in Table 3.4 and Figure 3.8 show that in Australia, in general, the percentage of casualty crashes resulting in FSI increases as the speed limit increases. This ranges from 17.9% in 0–30 km/h urban road environments to 55% in 110 km/h rural road environments.

This trend also applies in New Zealand but with two anomalies, the 90 km/h speed limit in rural environments and the 0–30 km/h speed limit in urban environments.

In New Zealand, the results show that the 90 km/h rural environment contributes the highest percentage of casualty crashes, resulting in FSI at 60%. However, as the number of injury crashes is five, with three resulting in FSI, compared to 7802 injury crashes for 100 km/h, the sample size for 90 km/h is not sufficient to be included as part of the analysis. It is therefore concluded that the higher the speed limit, the higher the percentage of FSI crashes; with the highest being 30.6% of injury crashes on 100 km/h speed limit roads.

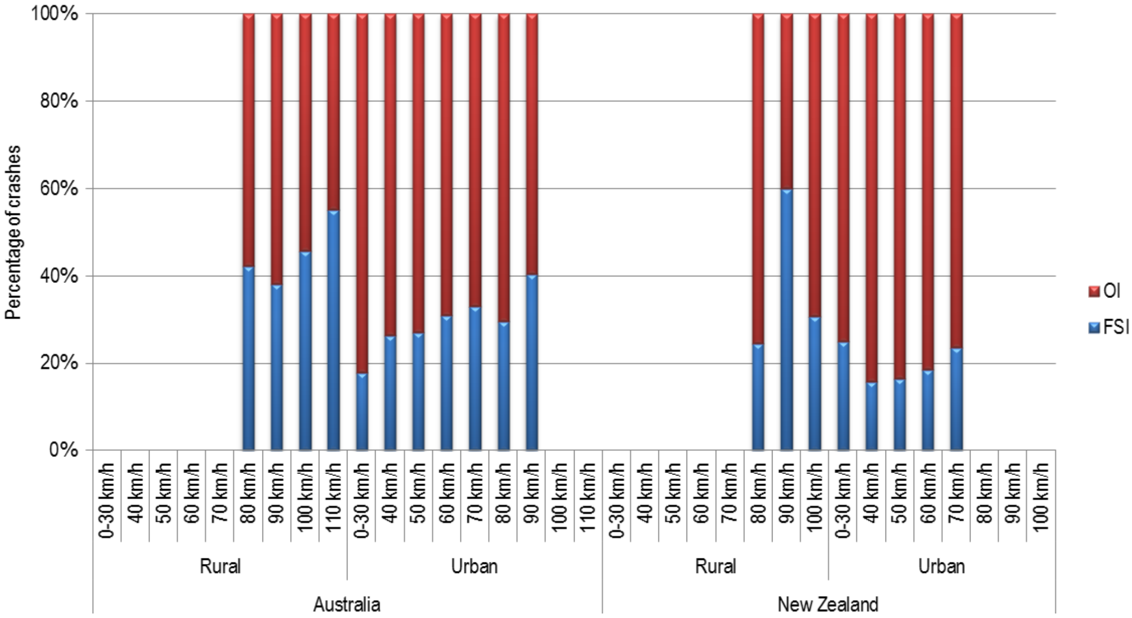
The New Zealand urban road environment results show that speed limits of 0–30 km/h contribute a higher percentage of FSI crashes (at 25%) than any other in this environment. As 30 km/h is also used as a temporary speed limit and had not been widely used in other road environments during the study period 2006–10, it is unclear from the results below as to the location and circumstance of these crashes. This is assumed as the results for the 50 km/h speed limit show that most of the urban injury crashes occur in this speed limit, with 27 195 injury crashes resulting in 16.4% of FSI crashes, almost 9% less than the percentage of FSI crashes for the 30 km/h speed limit.

Table 3.4: Casualty crashes by speed limit (2006–10) LG-managed roads

Country	Area	Injury type	Speed (km/h)								
			0–30	40	50	60	70	80	90	100	110
Australia	Rural	FSI	–	–	–	–	–	2 472 (42.1%)	190 (38.1%)	4 596 (45.6%)	617 (55%)
		OI	–	–	–	–	–	3 398 (57.9%)	307 (61.9%)	5 482 (54.4%)	504 (45%)
		Total	–	–	–	–	–	5 870 (100%)	497 (100%)	10 078 (100%)	1 121 (100%)
	Urban	FSI	101 (17.9%)	594 (26.3%)	15 334 (27.1%)	14 773 (30.9%)	1 952 (33%)	132 (29.5%)	6 (40.4%)	–	–
		OI	464 (82.1%)	1 665 (73.7%)	41 292 (72.9%)	32 998 (69.1%)	3 962 (67%)	314 (70.5%)	10 (59.6%)	–	–
		Total	565 (100%)	2 259 (100%)	56 626 (100%)	47 771 (100%)	5 914 (100%)	446 (100%)	16 (100%)	–	–
New Zealand	Rural	FSI	–	–	–	–	–	312 (24.4%)	3 (60%)	2 387 (30.6%)	–
		OI	–	–	–	–	–	967 (75.6%)	2 (40%)	5 415 (69.4%)	–
		Total	–	–	–	–	–	1 279 (100%)	5 (100%)	7 802 (100%)	–
	Urban	FSI	105 (25%)	3 (15.8%)	4 461 (16.4%)	141 (18.5%)	296 (23.5%)	–	–	–	–
		OI	315 (75%)	16 (84.2%)	22 734 (83.6%)	622 (81.5%)	961 (76.5%)	–	–	–	–
		Total	420 (100%)	19 (100%)	27 195 (100%)	763 (100%)	1257 (100%)	–	–	–	–

Source: ARRB Group.

Figure 3.8: Casualty crashes by speed limit (2006–10) LG-managed roads



Source: ARRB Group.

3.2.7 Horizontal and Vertical Alignment

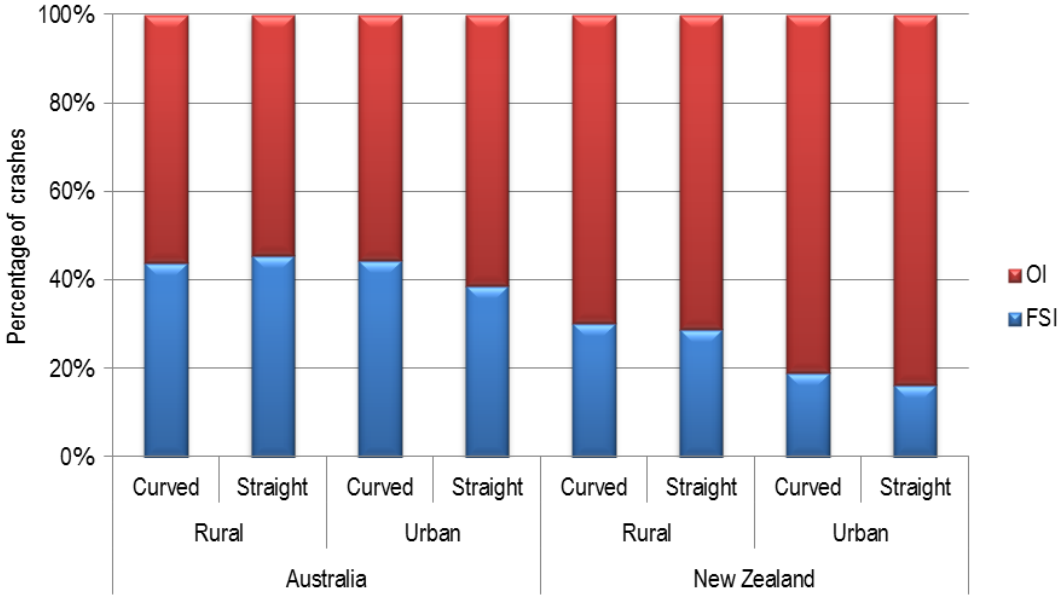
Figure 3.9 shows the results for crashes on 'straight' and 'curved' roads on rural and urban local roads. The results show that the percentage of FSI crashes is similar for both 'curved' and 'straight' roads in the rural environment, with over 40% in Australia and approximately 30% in New Zealand.

On urban roads, the percentage of FSI crashes is higher on 'curved' roads than 'straight' roads. The result is similar for both Australia and New Zealand.

The percentage of FSI crashes for vertical alignments is shown in Figure 3.10. As with horizontal alignment, crashes on rural roads show the same percentage of FSI crashes for all vertical alignments, with approximately 50% in Australia and 30% in New Zealand.

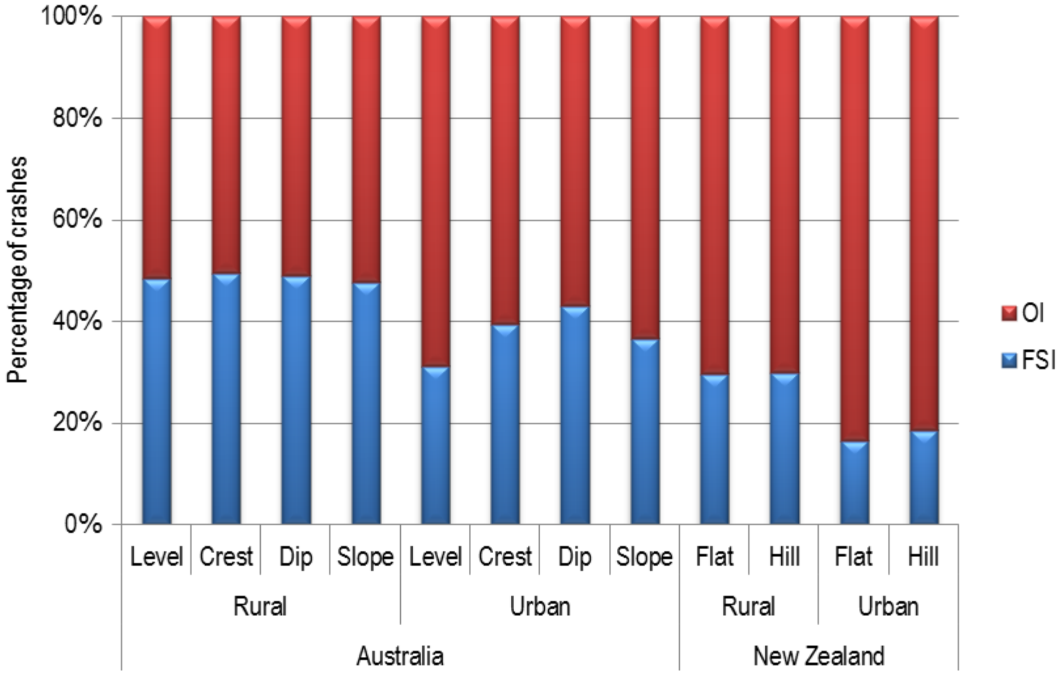
A lower percentage of casualty crashes result in FSI on urban roads than for rural roads, with a higher percentage occurring on 'dips' followed by 'crests' in Australia. In the New Zealand urban environment, a slightly higher percentage of casualty crashes resulting in FSI occur on 'hill' than 'flat'.

Figure 3.9: Casualty crashes by horizontal alignment (2006–10) LG-managed roads



Source: ARRB Group.

Figure 3.10: Casualty crashes by vertical alignment (2006–10) LG-managed roads



Source: ARRB Group.

3.2.8 Surface Characteristics

Figure 3.11 shows that in general, more crashes result in FSI on rural than on urban roads on all types of road surface characteristics.

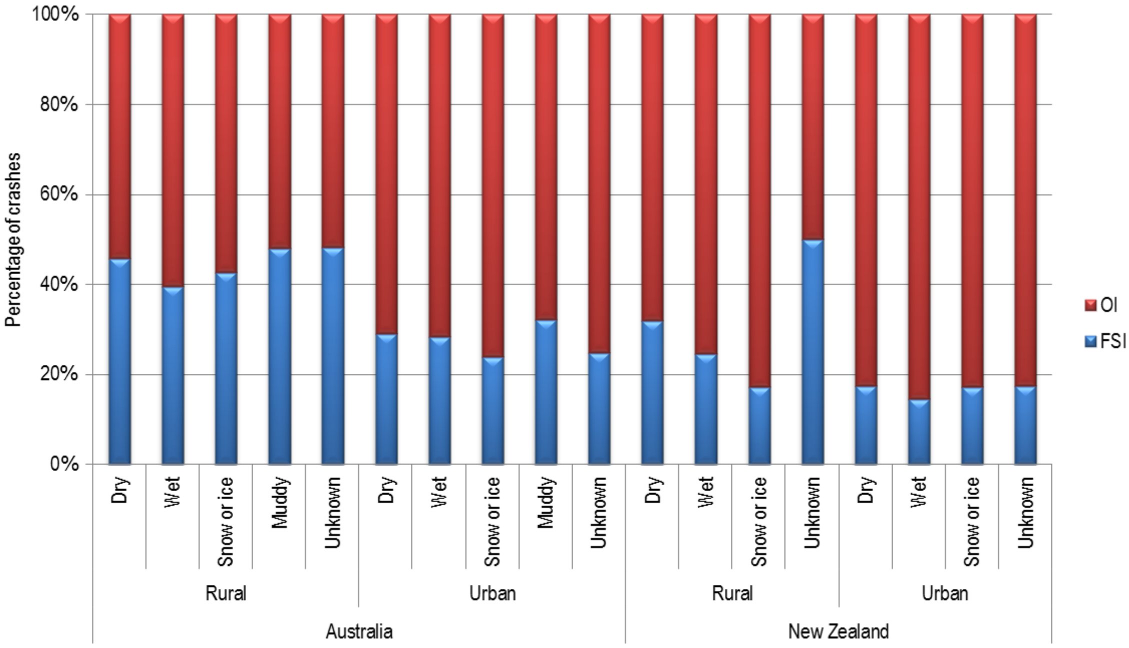
In Australia in both rural and urban environments, ‘muddy’ road surface conditions result in the highest percentage of FSI crashes at approximately 50%. In the rural environment, ‘dry’ surface conditions have the second highest percentage of FSI crashes at approximately 45%.

In Australian urban environments, both ‘dry’ and ‘wet’ surface conditions produce the second highest percentage of FSI crashes at approximately 30%.

In New Zealand, injury crashes on ‘dry’ surface conditions result in a higher percentage of FSI crashes than on ‘wet’ or ‘snow/ice’ conditions in rural areas at over 30%. In urban areas, ‘dry’ conditions produce a similar percentage of FSI crashes as ‘snow/Ice’ conditions at around 18%.

It is noted that the ‘unknown’ surface condition has a high percentage of FSI crashes in both Australian and New Zealand rural environments.

Figure 3.11: Casualty crashes by surface characteristics (2006–10) LG-managed roads



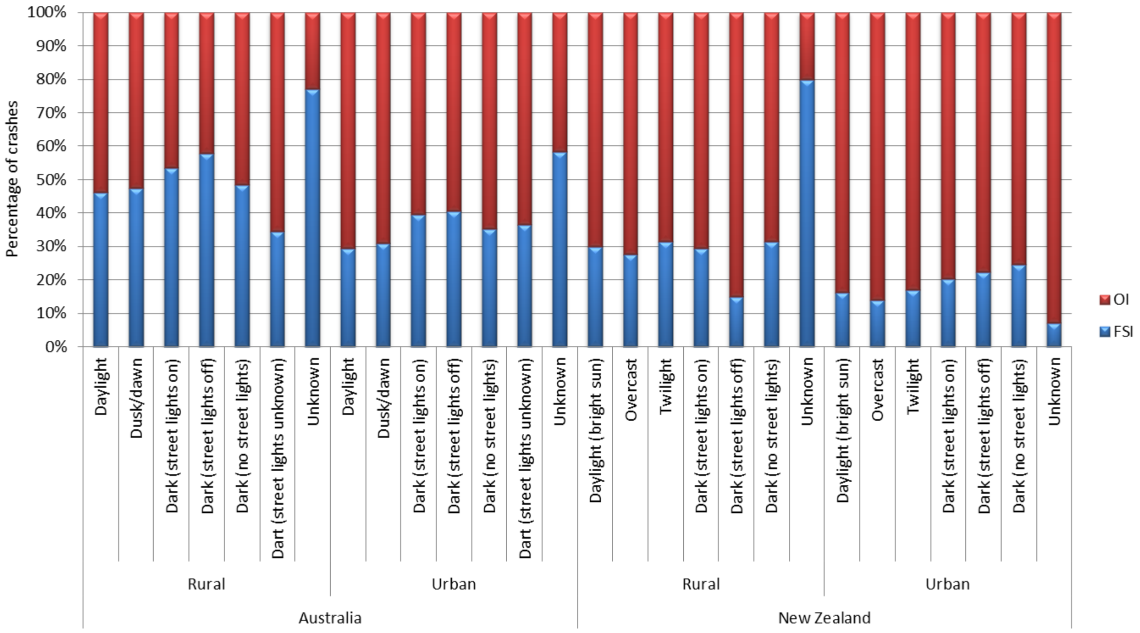
Source: ARRB Group.

3.2.9 Light Condition

Figure 3.12 shows that in Australia, casualty crashes in darkness have a higher percentage of FSI crashes than other light conditions in both rural and urban environments. Darkness with lights off has only a slightly higher percentage than darkness with lights on. Casualty crashes in daylight and dusk/dawn conditions result in a similar percentage of FSI.

In New Zealand, there is a difference between rural and urban environments. In the rural environment, except for darkness with lights on, which has the lowest percentage of FSI crashes, all other light conditions have a similar percentage of FSI of around 30%. In the urban environment, darkness has a higher FSI than any other light condition. In general, casualty crashes in dark conditions result in a higher percentage of FSI than in light, overcast or twilight conditions.

Figure 3.12: Casualty crashes by light condition (2006–10) LG-managed roads



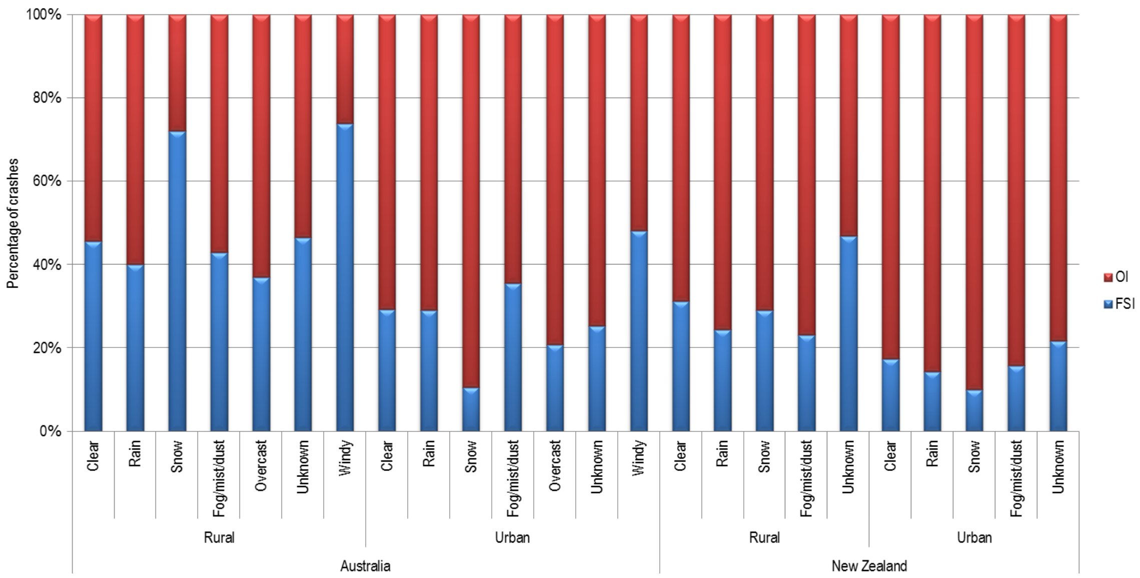
Source: ARRB Group.

3.2.10 Atmospheric Condition

In Australia, 'windy' conditions is the highest contributing factor to FSI crashes in both rural and urban environments, as shown in Figure 3.13. In the rural environment, 'snow' conditions contribute the same percentage of FSI crashes as 'windy' and are approximately 10% higher than other conditions. 'Clear' and 'rain' conditions contribute a similar percentage of FSI crashes in both rural and urban environments.

The data for New Zealand does not have 'windy' as a contributing factor. The results show that 'clear' conditions contribute a higher FSI as a percentage of casualty crashes than other atmospheric conditions for both rural and urban environments.

Figure 3.13: Casualty crashes by atmospheric conditions (2006–10) LG-managed roads



Source: ARRB Group.

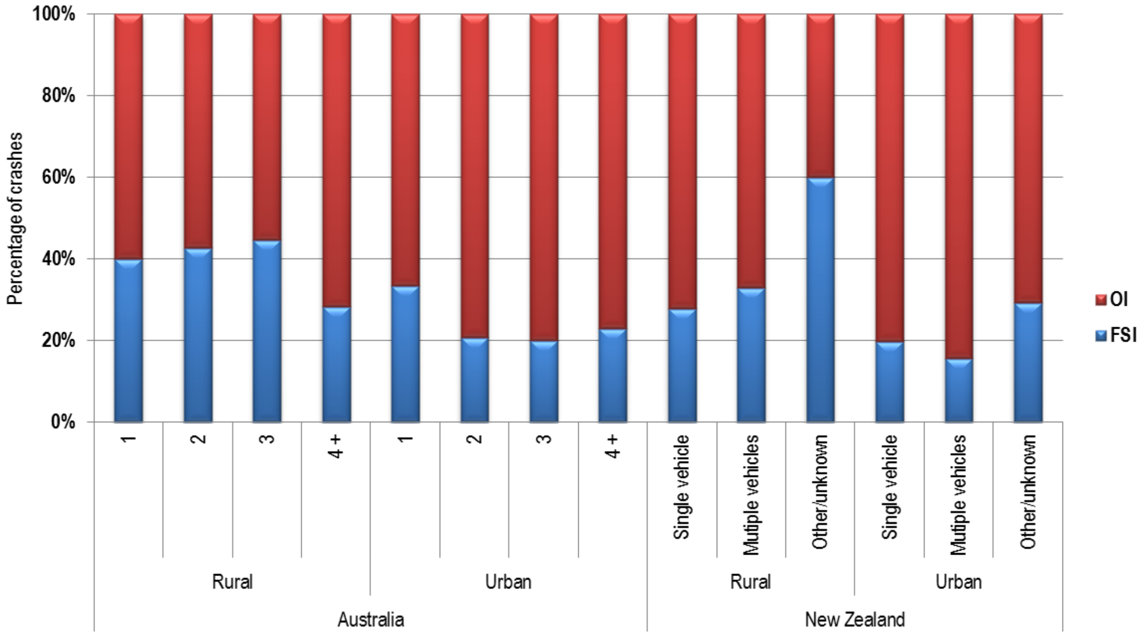
3.2.11 Number of Traffic Units

Figure 3.14 shows that on rural roads, two and three units in Australia and multiple units in New Zealand contribute to a higher percentage of FSI than single units.

On urban roads, single units contribute a higher percentage of FSI than multiple units.

Casualty crashes in Australia involving four plus units have a higher percentage of FSI in the rural than the urban environment.

Figure 3.14: Casualty crashes by number of traffic units (2006–10) LG-managed roads



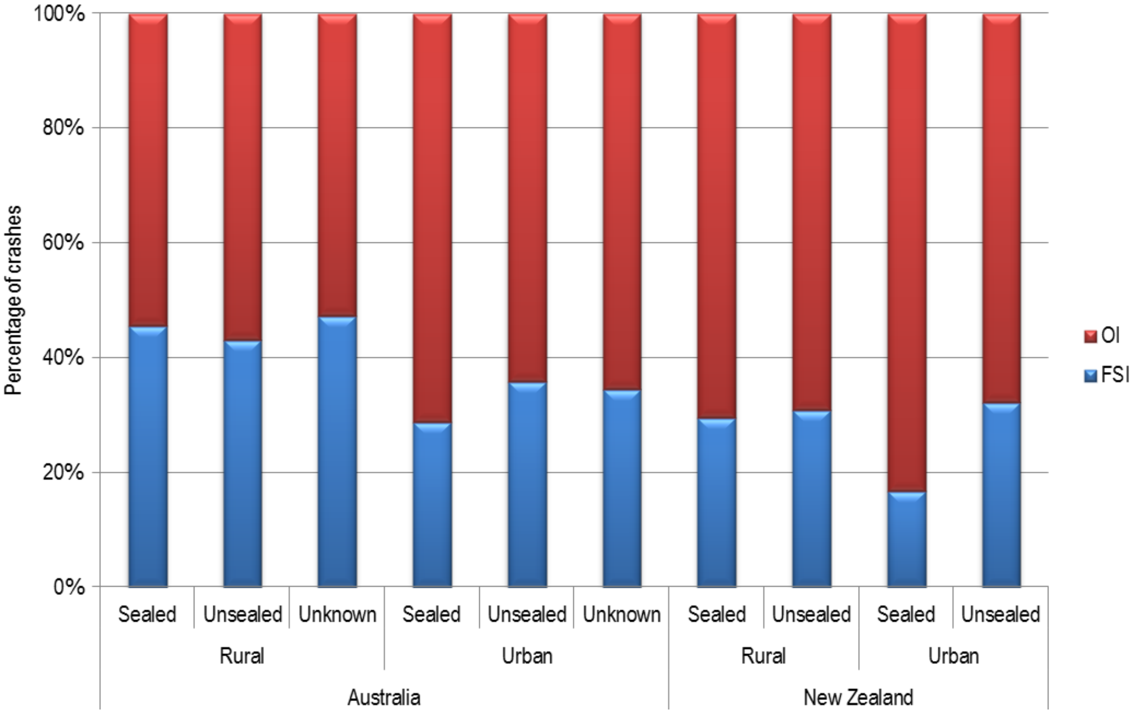
Source: ARRB Group.

3.2.12 Surface Type

In rural environments for both Australia and New Zealand, the results in Figure 3.15 do not show a significant difference in the percentage of FSI for sealed and unsealed roads. There is, however, a higher percentage of FSI on unsealed roads in the urban environment.

The results also show the same trend as in most other contributing factors, in that the percentages of FSI are higher in rural than in urban environments. In general, the percentage of casualty crashes resulting in FSI is higher in Australia than New Zealand.

Figure 3.15: Casualty crashes by number of surface type (2006–10) LG-managed roads



Source: ARRB Group.

3.3 Discussion of Analysis Results

The analysis of crash characteristics on local government roads is presented in Section 3.2.1 to Section 3.2.12. Crash data used in the analysis was for the five-year period 2002–06, whereas the analysis by year used 10 years of data from 2001–10.

The local road network in Australia accounts for 46% of FSI crashes, with 35% occurring in urban road environments and 8% in rural. In New Zealand, the percentage is higher at 63%, with 41% in urban road environments and 22% in rural. The urban road environment contributes a higher percentage of FSI crashes than the rural in both countries.

These percentages have not significantly changed over the 10 years (2001–10) and neither have the total number of injury crashes in the rural road environment. However, a reduction in total injury crashes has occurred on urban roads, with the percentage of FSI crashes remaining unchanged.

The crash types along with nine contributory factors assessed in this report reflect the same trend when comparing rural with urban roads. When comparing the total percentage of FSI crashes for the whole network of Australia and New Zealand, a higher percentage of FSI crashes result from the total injury crashes on rural roads than urban roads.

Therefore, although the number of injury crashes and those resulting in FSI are greater on urban roads, an injury crash occurring in a rural environment is more likely to result in FSI than in an urban environment. This is due to the different factors associated with the two road environments and in particular the higher speed limits on rural roads compared to the lower speed limits in urban road environments.

These factors are discussed in the following sections where the number of crashes refers to the five-year analysis period.

Crash types

The crash type with the highest percentage of FSI, in both Australia and New Zealand, is that involving pedestrians and is much higher in rural than urban environments. As this type of crash involves the most vulnerable of all road users, it is expected that a pedestrian injury crash has a higher likelihood of FSI.

Although the number of injury crashes for this crash type is not high in the rural environment (161 in Australia, 105 in New Zealand), it is alarmingly high in the urban environment, with 13 195 in Australia and 5259 in New Zealand. In both rural and urban environments, regardless of the total number of injury crashes, the percentage resulting in FSI is considered to be extremely high. It is 74.5% (rural) and 41.1% (urban) in Australia, and 54.3% (rural) and 26.8% (urban) in New Zealand.

In rural environments, the second highest percentage of FSI occurs from the ‘opposing direction’ crash type. This is the case for both Australia (57.9%) and New Zealand (39.7%). The number of injury crashes occurring as a result of this crash type (1365 in Australia and 1184 in New Zealand) is not considered high when compared to other crash types. However, this type of crash produces a higher severity than other crash types outside of the ‘pedestrian’ crash type.

Other significant crash types in the rural environment in Australia are: ‘overtaking’, ‘off path on straight’ and ‘intersection’ with around 50% FSI; and in New Zealand: ‘overtaking’, ‘intersection’ and ‘manoeuvring’ at around 30% FSI.

The highest total number of injury crashes occurring on rural road environments in both countries is associated with the crash type ‘off path on bend’, with a total of 6502 crashes in Australia and 4349 crashes in New Zealand. Although this type of crash is associated with a lower percentage of FSI than most other crash types (42.5% in Australia, 28.2% in New Zealand), it is still considered significant.

In urban road environments in both Australia and New Zealand, three crash types have similar percentages of FSI and should be considered as second. These are ‘off path on straight’, ‘overtaking’ and ‘off path on bend’, with FSI ranging from 35.9–37.8% in Australia and 18–20.9% in New Zealand.

The crash type ‘overtaking’ has considerably lower total injury crashes than the other two crash types (841 in Australia, 692 in New Zealand), but results in a reasonably high percentage of FSI.

The highest total number of injury crashes occurring on urban road environments in both countries is associated with two crash types, ‘same direction’ and ‘intersection (adjacent)’. There is only a small difference between the two crash types in total injury crashes: approximately 23 000 in Australia and 5500 in New Zealand for each crash type. However, these crash types produce lower percentages of FSI than most other crash types, with the ‘same direction’ producing the lowest percentage of FSI (16.4% in Australia and 7.7% in New Zealand).

Reducing the percentage of FSI is a priority for all crash types; however, priority should be given to crash types that produce the highest percentage of FSI such as the ‘pedestrian’ crash types in both rural and urban road environments.

Mid-block/intersection

Injury crashes associated with three locations have been analysed, the ‘cross intersection’, ‘T-intersection’ and ‘not at intersection’. A category ‘other/unknown’ is also included as part of the analysis, but does not form part of the discussion.

The location ‘not at intersection’ is associated with the highest number of injury crashes in both Australia and New Zealand, in both rural and urban road environments. However, the severity of the crashes varies for the different road environments.

This location has a higher percentage of FSI in the urban environment in both countries (31.7% in Australia, 19.1% in New Zealand) than the other locations. Whereas in the rural environment, the location ‘cross intersection’ is associated with a higher percentage of FSI than any of the other locations.

In the urban environment, both locations of ‘cross intersection’ and ‘T-intersection’ have a similar crash severity outcome in both Australia and New Zealand. However, the ‘T-intersection’ has a higher number of injury crashes.

Injury crashes at all three locations have a significant percentage of FSI, with the difference being a maximum of 6% between all three locations in both rural and urban environments.

Speed limit

The highest number of injury crashes is on roads with a 100 km/h speed limit in the rural road environment and 50 km/h speed limit in the urban road environment. This is expected as these are the default speed limits and would therefore be associated with a larger number of roads than any other speed limits.

The high number of injury crashes found on the 50 and 100 km/h roads discussed above, do not produce the highest percentage of FSI, as this is found to increase with increasing speed limits. In Australia, the lowest FSI is on 0–30 km/h speed limit urban roads (17.9%) and the highest FSI is on 110 km/h speed limit rural roads (55%).

Injury crash results for New Zealand are for a maximum of 100 km/h, which results in 30.6% FSI. The FSI on a 40 km/h speed limit road is 15.8%.

The results show that the higher the speed limit, the greater the severity of the crash.

The exception in the results is the 0–30 km/h speed limit in the New Zealand urban environment, with 25% FSI. This speed limit is also used as a temporary speed limit and had not been widely used in other road environments during the study period 2006–10; it is unclear from the results as to the location and circumstance of these crashes.

Road user contribution

‘Alcohol’ is the highest road user contributing factor to the percentage of injury crashes resulting in FSI in both Australia and New Zealand in rural and urban road environments. In Australia, ‘fatigue’ is the second contributing factor ahead of ‘speed’ in rural road environments. This is the reverse in urban road environments, with ‘speed’ having a higher contribution to FSI than fatigue. This result is as expected with the long distances travelled in rural road environments contributing to fatigue.

New Zealand only has ‘alcohol’ and ‘speed’ as contributing factors.

Road geometry

When considering the vertical and horizontal road alignment, it is found that in the rural road environment in both Australia and New Zealand, there is no significant difference in the effect of the various contributing factors.

The contributing factors in horizontal alignment of ‘curved’ and ‘straight’ is just over 40% FSI in Australia and approximately 30% FSI in New Zealand.

The contributing factors in vertical alignment of ‘level’, ‘crest’, ‘dip’ and ‘slope’ all contribute approximately 50% FSI in Australia. In New Zealand, ‘flat’ and ‘hill’ each contribute approximately 30% FSI.

In the urban environment, there is a difference in the contribution level to FSI from each of the factors. In Australia, ‘dip’ is the highest contributor at over 40%; and in New Zealand, ‘hill’ is the highest contributor with approximately 20%.

Surface characteristics and surface type

The surface characteristic of ‘muddy’ is the highest contributing factor in Australia in both rural and urban road environments, followed by ‘dry’ conditions. New Zealand does not have ‘muddy’ factor, with the results showing that ‘dry’ surface conditions are the highest contributing factor to FSI.

As has been found with other contributing factors, road surface conditions in the rural road environment do not have a significant difference in contributing to percentage of FSI. ‘Sealed’ and ‘unsealed’ roads have a similar percentage of FSI, over 40% in Australia and approximately 30% in New Zealand.

In the urban road environment, ‘unsealed’ has a significantly higher percentage of FSI than ‘sealed’.

Atmospheric and light conditions

In Australia, the atmospheric condition of ‘windy’ has a significantly higher contribution to the percentage of FSI crashes than other conditions on urban roads, at approximately 50%. In rural roads, both ‘windy’ and ‘snow’ each contribute a high percentage to FSI crashes (approximately 70%). This differs from New Zealand, where ‘clear’ conditions are the highest contributors to FSI crashes in both rural and urban road environments.

The light condition ‘darkness’ is commonly the highest contributor to percentage of FSI crashes in both countries, in the rural and urban road environments. There is only a minor difference between lights and no lights, with the latter having a higher contribution to the percentage of FSI crashes.

Number of traffic units

The results show that in rural environments, crashes resulting from multiple units of traffic have a higher percentage of FSI; whereas in urban road environments, crashes involving single vehicles have a higher percentage of FSI. This is the case for both Australia and New Zealand.

3.4 Conclusions

The crash type with the highest percentage of FSI crashes on local government-managed roads is ‘pedestrian’, for both Australia and New Zealand, in rural and urban environments.

The results of the other crash types differ between rural and urban road environments and in some cases between Australia and New Zealand.

In addition to the ‘pedestrian’ crash type, the other significant crash types include:

- Rural road environment
  - ‘opposing direction’ in Australia and New Zealand (the second highest percentage of FSI crashes)
  - ‘overtaking’, ‘off path on straight’ and ‘intersection’ in Australia
  - ‘overtaking’, ‘intersection’ and ‘manoeuvring’ in New Zealand.
- Urban road environment
  - ‘off path on straight’, ‘overtaking’ and ‘off path on bend’ in Australia and New Zealand.

All ten factors analysed contribute in different proportions to injury crashes for the different crash types. The factors considered to have higher contribution to injury crashes are ‘speed’ limit, the location of the crash ‘mid-block/intersection’ and the ‘light conditions’. Another significant contributory factor is ‘road user contribution’, where alcohol is the highest contributor to the percentage of FSI crashes.

Further detailed analysis that is outside the scope of this project is required to establish the connection between the main contributing factors of ‘speed, ‘mid-block/intersection’, ‘light conditions’ and ‘road user contribution’, and the crash types discussed above.

4. Safety Management System Development

4.1 Developing the Concept

A key component of the project is the investigation of a safety management system to assist local government to manage road safety on local roads. Austroads (2010a) briefly described what this safety management system should be like, outlining that it should provide '...comprehensive processes for achieving the goal of safety...' and include '...goal setting, planning and measuring performance. The safety management system aims to embed safety within the organisational culture and the way that people do their jobs.'

More recent Austroads projects have investigated opportunities for a systematic means of facilitating the Safe System approach into the operations of organisations responsible for the management of road networks. Two of these are:

- Safety Management Systems for Road Agencies: ISO 39001 and the Next Step Towards a Safe Road Transport System (Austroads 2015c).
- Safe System Assessment Framework (Austroads 2016).

Other projects have investigated the degree of effectiveness of infrastructure treatments to achieve Safe System objectives. One of particular relevance is titled *Improving the Performance of Safe System Infrastructure* (Austroads 2015d).

These projects have only recently published their findings. Therefore, investigations for this project considered early findings to assist the development of a parallel process that is applicable to local government.

Consultation with the project working group about a safety management system identified that local government practitioners generally lacked the following:

- a clear framework for evaluating their road network against the principles of the Safe System approach to road safety
- a means of clearly communicating to colleagues within their council (both technical and non-technical), to their managers, the elected representatives and to members of the community, the road safety issue that exists at a site or along a road within a Safe System context.

To address this, it was determined that a safety management system for local government should:

- be developed utilising techniques familiar to council practitioners, to improve the likely take-up and understanding across the organisation
- be firmly embedded in the vision and principles of the Safe System approach, i.e. to eliminate death and serious injury from road crashes, by recognising that road users will make mistakes and road environments should be designed and operated to manage crash impact forces to within levels tolerable to the human body
- include consideration of road safety issues using all of the Safe System pillars, to maximise the scope for local government to develop and implement countermeasures and other actions.

Additionally, to ensure as broad an application as possible within local government, the approach should be:

- readily accessible to practitioners at all levels of council and across disciplines and functional areas
- scalable, so that it can be applied at the project level as readily as it can at the route and road network level
- simple to replicate and adaptable, so it can fit a council's site investigation process, or equally, communicate road safety needs via council's management plan.

A framework covering these points is expected to be of assistance to local government practitioners when seeking to address road safety issues within a Safe System context.

In developing the concept into a framework that can be applied by practitioners, the area of risk management has been combined with the Safe System approach. The basis for this and the resulting framework are discussed further in the next section.

4.2 The Safe System Hierarchy of Control Framework

4.2.1 The Safe System Hierarchy of Control in Context

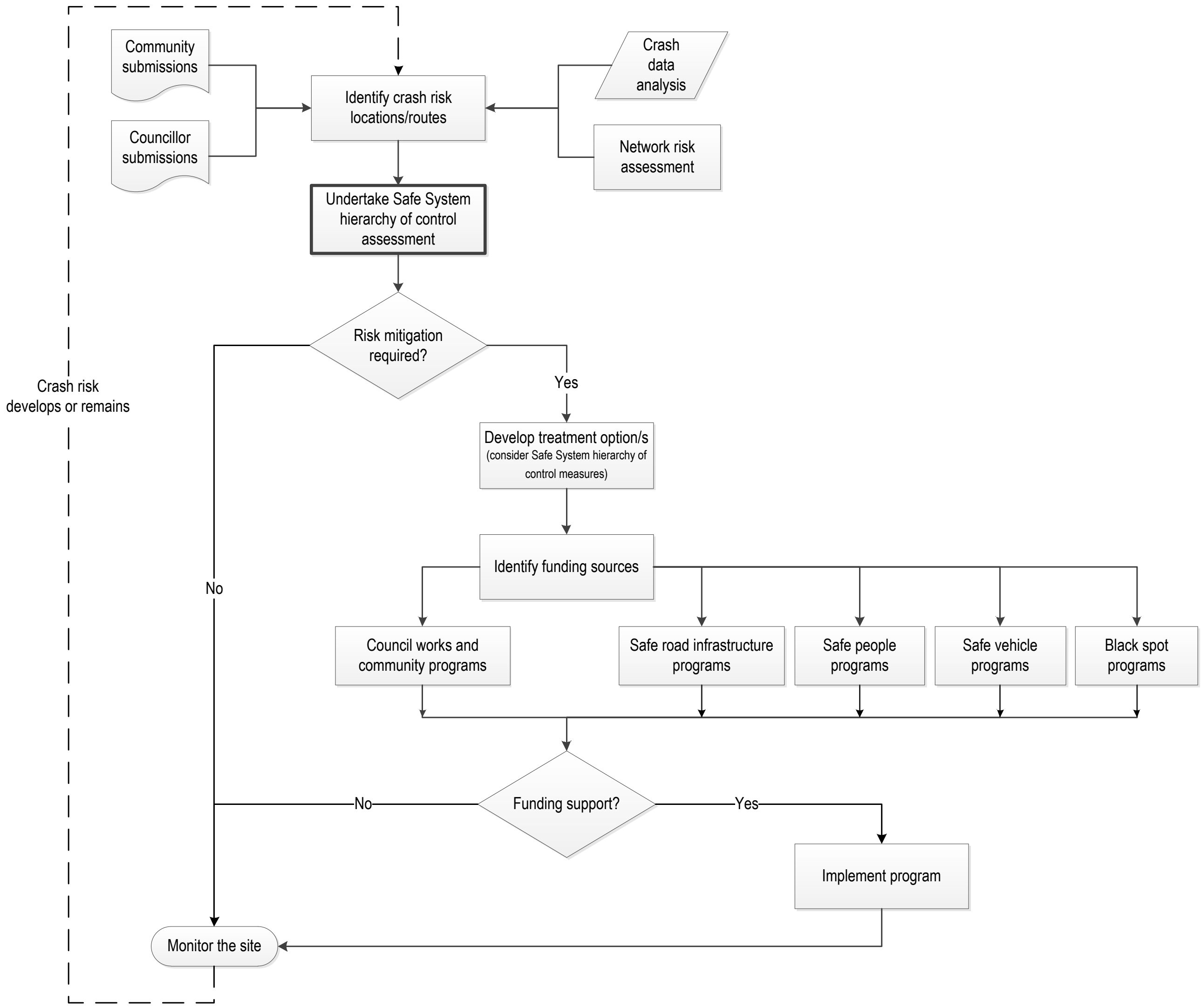
It is important to recognise that the Safe System Hierarchy of Control is a site assessment tool and this framework is a means to an end, not the end result.

There are a number of additional considerations required before a council should adopt any suggested action arising from the assessment. For example, estimating countermeasure costs, the effectiveness to reduce the crash incidence and severity, the feasibility of suggested treatments, sources of funding, project staging, and support for the treatment technically and from the community, particularly where the funding is from a state or federal black spot program.

Additionally, consideration should be given to how the treatments fit within the council's strategic management plan and capability to deliver road safety objectives.

Figure 4.1 provides an overview of how the assessment framework fits into the context of delivering road safety programs.

Figure 4.1: Overview for managing and delivering road safety on local roads



Source: ARRB Group.

4.2.2 Risk Management and the Hierarchy of Control

Risk management is a well-established process in industry and was previously documented in AS/NZS 4360:2004 *Risk Management*. This Standard has since been superseded by ISO 31000: 2009, but the framework for evaluating risk management options remains in place.

In terms of risk in a road management context, the Austroads *Guide to Road Safety Part 7: Road Network Crash Risk Assessment and Management* (Austroads 2006b) also provides a framework for risk management and is focused on reducing road crashes.

Austroads (2006a) identifies three particular mechanisms that road managers can utilise to reduce the level of risk when treating the risk associated with road trauma. These include:

- reduction of exposure to the risk
- reduction in the likelihood of a crash (including the concept of a 'no surprises' environment)
- reduction in the severity of a crash (e.g. creating a more forgiving road environment).

Austroads (2006a) presents a Hierarchy of Control commonly applied in managing risk; it is perhaps most commonly known, particularly by local government practitioners, from its application in workplace health and safety. The Hierarchy of Control method outlined collates remedial treatments based on the level of risk reduction likely to be achieved, and is as follows:

1. Elimination – remove the hazard.
2. Substitution – use a safer option.
3. Engineering controls – in terms of design modifications.
4. Isolation – where the hazard is removed from direct influence.
5. Administrative controls – including educational initiatives, speed limits, licensing, drink driving laws.
6. Personal protective equipment – for example, vehicle improvements (air-bags, electronic stability control, etc.).

ISO 31000:2009 presents a cyclical process to treat risks that involves selecting one or more options for modifying risk, and then implementing those options. Once implemented, treatments provide or modify the controls. The treatment of risk involves a cyclical process of:

- assessing a risk treatment
- deciding whether residual risk levels are tolerable
- if not tolerable, generating a new risk treatment
- assessing the effectiveness of that treatment.

ISO 31000:2009 presents risk treatment options that are not necessarily mutually exclusive or necessarily appropriate in all circumstances. The options may include the following:

- avoiding the risk by deciding not to start or continue with the activity that gives rise to the risk
- taking or increasing the risk in order to pursue an opportunity
- removing the risk source
- changing the likelihood
- changing the consequences
- sharing the risk with another party or parties (including contracts and risk financing)
- retaining the risk by informed decision.

Often there is a suite of measures that can be implemented to manage a particular risk, with some measures typically more effective than others. The risk management Hierarchy of Control framework was developed to assist in understanding the relative effectiveness of different treatment options to reduce risk and assist in the decision-making process for selecting one risk treatment over another, taking into account various constraints, e.g. cost.

Within local government, the risk management Hierarchy of Control framework is well known and understood. While it is most commonly applied to workplace health and safety issues, local government practitioners are familiar with the levels of the hierarchy and with the process involved for evaluating and managing risk.

Utilising the strength from ISO 31000:2009 and Austroads (2006a), both risk treatment approaches have been combined to develop a road safety Hierarchy of Control as outlined in Table 4.1.

Table 4.1: Road safety Hierarchy of Control for treatment hierarchy

<table>
<tr><th>Hierarchy of Control level</th><th>Austroads (2006a)</th><th>IS0 31000:2009</th><th>Road safety Hierarchy of Control</th></tr>
<tr><td>1</td><td>Eliminate</td><td>Removing the risk source</td><td>Remove the risk</td></tr>
<tr><td rowspan="3">2</td><td>Substitute</td><td rowspan="3">Avoiding the risk by deciding not to start or continue with the activity that gives rise to the risk</td><td rowspan="3">Reduce the risk</td></tr>
<tr><td>Isolate</td></tr>
<tr><td>Engineer</td></tr>
<tr><td>3</td><td>Administration</td><td>Changing the likelihood</td><td>Change road user behaviour</td></tr>
<tr><td rowspan="4">4</td><td rowspan="4">Personal protective equipment</td><td>Changing the consequences</td><td>Protect the road user</td></tr>
<tr><td>Taking or increasing the risk in order to pursue an opportunity</td><td>Not applicable</td></tr>
<tr><td>Sharing the risk with another party or parties (including contracts and risk financing)</td><td>Not applicable</td></tr>
<tr><td>Retaining the risk by informed decision</td><td>Not applicable</td></tr>
</table>

Source: ARRB Group.

The four levels within the Hierarchy of Control framework are generic in nature and permit application to any risk scenario. Table 4.2 presents the generic levels of risk control in a road safety-based context. The effect of control for each level is outlined and examples of the types of treatments that fit the objectives of each level are provided.

Table 4.2: Road safety Hierarchy of Control treatment structure

Hierarchy	Risk control method	Effect of control	Example[1, 2]
1	Remove the risk	Remove the hazard from the road and traffic environment	• Remove a tree or utility pole from the roadside area • Grade separated pedestrian crossings • Fully separated cycleway.
2	Reduce the risk	Replace one hazard with another, less severe and more controllable, hazard Physically separate road users from the hazard to minimise road user interaction with it, or modify the design of the road infrastructure to reduce road user interaction with the hazard and/or assist road user control	• Road safety barrier • Roundabout (replacing priority controlled cross or T-intersection) • Wide median or verge area with or without a safety barrier • Traffic signal control pedestrian crossings • Off-road cycleway • Increase lane and sealed shoulder width • Improve delineation of the carriageway • Provide pedestrian crossing with refuge island • On-road cycleway and shared zones • Improve Australian New Car Assessment Program (ANCAP) rating of vehicle fleet.

Hierarchy	Risk control method	Effect of control	Example[1, 2]
3	Change road user behaviour	Provide warning/advice to seek appropriate behaviour	• Curve warning/speed advisory signs • Reduced speed limit and school zone alert signing • Vehicle safety features such as speed alerts, lane departure warning, blind-spot monitoring, etc. • Enforcement, education and training.
4	Protect the road user	Use equipment to protect road users from death/injury	• Seat belts, anti-lock braking system (ABS), electronic stability control (ESC), automatic emergency braking (AEB) • Pedestrian airbags and bonnet designs • Replace a rigid lighting pole with a frangible pole.

1 *The examples listed are not exhaustive. A range is provided to help illustrate the Hierarchy of Control approach.*
2 *Examples do not necessarily fall exclusively into one category of risk control.*

Source: ARRB Group.

4.2.3 The Safe System Approach

The Safe System approach has been promoted across Australia and New Zealand since 2005 and is the foundation of road safety strategic planning and action in both countries.

As a concept and principle to modern road safety, the Safe System approach has been promoted to local government practitioners through updates to the Austroads Guides since 2009. Local jurisdictions have also provided updates to practitioners via their technical directions, and Safe System principles have been a constant theme at road safety conferences since being adopted.

The Safe System pillars adopted in Australia and New Zealand are:

- safe roads and roadsides
- safe speeds
- safe people
- safe vehicles.

Internationally, a fifth pillar, emergency response and post-crash care, is often cited. While a valid element of the Safe System approach, there is very limited relevance to the majority of local government and so it has not been included in this project. However, there is no reason that a local council could not include this as a pillar where there is an involvement in or responsibility for a local volunteer rescue association (VRA), rural fire service (RFS) or country fire association (CFA), which may be a first responder to motor vehicle crashes.

The promotion and discussion of the Safe System approach with and amongst local government practitioners has ensured there is a broad awareness and understanding of it as a core principle to road safety. Local government practitioners involved in road safety and traffic management should certainly have an awareness of the pillars that support it, and have some idea for applying it in a local road context. Outside these practitioners, however, the paradigm and its principles may not be understood or known at all.

4.2.4 Developing a Safe System Hierarchy of Control Framework

In developing a safety management system for local government practitioners, an approach to combine the risk management Hierarchy of Control with the Safe System approach was considered to fit the project objectives.

In combining these two frameworks, a site/route assessment template was developed to assist practitioners to understand and apply it to their local roads (Table 4.3 and Table 4.4).

The features and approach to applying the template are outlined in the following overview:

1. Table 4.3 is intended to document the road safety issue under investigation. The upper section of the template permits a user to enter information about the site/route and the crash risk factors. These may include crash data, if it is available, or could be a description of the type of crashes that may occur, as for a proactive review where crashes are lacking.
2. The middle section of Table 4.3 seeks to assist establishing Safe System thinking about the site/route by requiring the practitioner to analyse the situation under each of the four Safe System pillars.
3. The lower section provides an area to insert site photographs, aerial/map images, plans, etc. in support of the analysis and describing the problem being reviewed.
4. Table 4.4 provides a matrix which combines the road safety Hierarchy of Control framework with the Safe System pillars.
5. The four levels of the Hierarchy of Control (i.e. matrix rows) represent the degree of risk mitigation, and the four pillars (i.e. matrix columns) represent the area of action.
6. This section is intended to engage the practitioner in a critical assessment of risk mitigation measures to address the road safety issues (i.e. hazard/crash type) identified at a site or along a specified route (in point 2, above). Note that risk mitigation measures can seek to address either a road hazard or a crash type[1], or both within the same matrix. This increases the scope of application of the framework to considering both reactive (crash/black spot investigations) and proactive (risk identification, resident concern) investigations.

The four levels of the Hierarchy of Control provide a ranking of risk mitigation measures listed by effectiveness to address the identified hazard/crash type.

The approach to completing this part of the framework intends that a practitioner identify risk mitigation measures as a brainstorming exercise, i.e. identify measures should not be restricted by prejudging the viability or affordability of a particular measure. The purpose of this is to provide a full understanding of the hazards/crash types/risks present at a site and of the full range of mitigation measures available. The intention is to make it clear how well, or broadly, the particular measures address the principles of the Safe System approach and under what pillars each measure falls.

With this information documented, a better-informed decision can be made about:

- the type of treatments that need to be funded and applied in order to achieve a desired level of risk mitigation
- the level of risk mitigation that can be achieved for a preferred (e.g. affordable) measure
- the pillars of the Safe System approach that are addressed by each measure
- whether there are gaps in the Safe System treatment of a site/route/hazard/crash type
- which department (or discipline) in council has responsibility to address certain aspects of an identified road safety issue.

Once compiled, the completed template can be used to assist in communicating a site or route assessment to colleagues, management, elected officials and the community. It provides a structured documentation of road safety issues, the risks posed to road users, and options prioritised by risk to mitigate them.

Table 4.3 and Table 4.4 are the templates that illustrate the Safe System Hierarchy of Control framework. They have explanatory text that guides the reader through the process to complete it.

[1] A hazard is a feature or element of the road environment that may cause or contribute to a road crash, or may contribute to the crash severity (e.g. roadside trees and utility poles if impacted will likely result in severe casualty outcomes, whereas a lack of delineation may contribute to a driver losing control but will not necessarily alter the crash severity).

As part of the project, a number of case study locations, nominated by members of the project working group, have been assessed using the Safe System Hierarchy of Control framework. These case study assessments are presented in Appendix B and are briefly discussed in the following section.

The case study assessments have also been uploaded to the Road Safety Engineering Toolkit for ready access by practitioners as examples of this type of site evaluation. Further information about this output of the project is presented in Section 5.

Table 4.3: Safe System Hierarchy of Control – site conditions pro-forma

<table>
<tr><th colspan="2">Site description (provide an outline of the current site configuration, key features of construction, traffic management, etc.)</th></tr>
<tr><td colspan="2">• Provide an outline of the road and traffic arrangements at the site, covering the geometry, speed limit, signing, delineation, condition, roadside, etc.
• Describe road user interactions and limitations of infrastructure to provide for all road users.
• If available, summarise the crash history of the site (three and five years, FSI outcomes, top three crash types, dominant road/weather conditions, etc.).</td></tr>
<tr><td colspan="2">Crash risk identification (briefly summarise the crash experience and/or type of road safety issue/s at the site)</td></tr>
<tr><td colspan="2">Outline the road safety concerns that are present at the site; cross-reference crash data, road safety audit issues, observations of contributing behaviour from assessors, and how issues under the Safe System pillars might contribute to crashes or safety concerns.</td></tr>
<tr><td colspan="2">Safe System pillar analysis (identify hazards and road safety issues grouped under the relevant pillar)</td></tr>
<tr><td>Safe roads:
• What is it about the road that contributes to the safety concerns/problem?</td><td>Safe people:
• What is it about road users and their behaviour that contributes to the safety concerns/problem?</td></tr>
<tr><td>Safe speeds:
• What is it about the road speed environment that contributes to the safety concerns/problem and FSI severity of the crash?</td><td>Safe vehicles:
• What is it about the road/vehicle interaction that contributes to the safety concerns/problem?</td></tr>
<tr><td colspan="2">Site photographs (supplement the site description and problem definition using selected site photographs)</td></tr>
<tr><td>Provide a map or aerial image of the site/route.</td><td>Provide images that highlight safety concerns, illustrate crash locations.</td></tr>
</table>

Source: ARRB Group.

Table 4.4: Safe System Hierarchy of Control – site evaluation pro-forma

<table>
<tr><th rowspan="2">Crash type</th><th rowspan="2">Cause/hazard</th><th rowspan="2">Control method</th><th colspan="4">Safe System pillars</th></tr>
<tr><th>Safe roads</th><th>Safe speeds</th><th>Safe people</th><th>Safe vehicles</th></tr>
<tr><td colspan="7">Remove the risk</td></tr>
<tr><td>Describe the particular type/s of road crashes under consideration.</td><td>Describe the contributing factors to the cause of the crash (or potential crash), or the type of hazard under consideration.</td><td>What mitigation measures could be adopted to remove the hazard, or the likelihood of the particular type of crash resulting in a fatal/serious injury outcome?</td><td>✓</td><td></td><td></td><td>✓</td></tr>
<tr><td colspan="7">Reduce the risk</td></tr>
<tr><td>Describe the particular type/s of road crashes under consideration.</td><td>Describe the contributing factors to the cause of the crash (or potential crash), or the type of hazard under consideration.</td><td>What range of control measures could be adopted to isolate/separate road users from the hazard, or the likelihood of the particular type of crash resulting in a fatal/serious injury outcome?</td><td>✓</td><td>✓</td><td>✓</td><td></td></tr>
</table>

Crash type	Cause/hazard	Control method	Safe System pillars			
			Safe roads	Safe speeds	Safe people	Safe vehicles
Change road user behaviour						
Describe the particular type/s of road crashes under consideration.	Describe the contributing factors to the cause of crashes (or potential crashes), or the type of hazard under consideration.	What type of control measures could be adopted to inform and warn road users about the hazard, or the likelihood of the particular crash type fatal/serious injury outcome?		✓	✓	
Protect the road user						
Describe the particular type/s of road crashes under consideration.	Description of the type of hazard or particular crash type under consideration.	What type of measures could be adopted to protect road users from the hazard, or the likelihood of the particular type of crash resulting in a fatal/serious injury outcome?			✓	✓

Note: The Safe System pillar checked with a tick is for illustrative purposes only.
Source: ARRB Group.

4.2.5 Safe System Hierarchy of Control – Case Study Assessments

The development of the Safe System Hierarchy of Control framework was trialled using a selection from the 100 locations nominated by the project working group. A cross-section of road environments and safety issues was included in the case study sites to confirm the validity of the framework and cover the broad range of road safety issues commonly faced by local government practitioners.

The case study assessments involved visiting the selected sites to observe and document road conditions, safety issues, and user behaviours relevant to the identified safety concerns. Some case studies involved crash data, reflecting a reactive investigation approach typical of black spot assessments; while other locations did not have any crash data available, representing issues that may have been raised by the local community or elected officials.

4.2.6 Using the Outcomes of the Safe System Hierarchy of Control

A review of the case studies highlight several potential uses by local government practitioners of the outcomes of a Safe System Hierarchy of Control assessment. The format is relatively straightforward to understand and can be adapted to:

- form part of a report to:
  - the local traffic committee – proposing potential action to council about a site
  - the project design team – identifying areas to focus on for developing countermeasures
  - council management and/or elected officials – communicating a risk management priority when allocating funding or formulating the action for council to take on a matter
  - council insurers and/or legal representatives in liability matters – documenting the range of potential measures that could have prevented or reduced the risk of an incident
- work across council department areas to:
  - brainstorm measures to address road safety concerns at a site, along a route, on a type of road or road environment, or across the local government area
  - document actions to be taken in response to a road safety matter
- communicate and work with other government agencies and external partners to align/coordinate complementary local-level interventions
- communicate with local residents the issues identified by council for a site and the context of a particular treatment that the local community is seeking versus other options of higher, lower or equivalent risk mitigation effectiveness.

5. Road Safety Engineering Toolkit (RSET)

To ensure the Safe System Hierarchy of Control is readily accessible to local government practitioners, the RSET website has been updated as a part of this project. The update of the website has included the following:

- Addition of a new area of the RSET that presents a selection of Safe System Hierarchy of Control case studies and information. User selection of the case studies is via an additional drop-down selection menu on the RSET front page.
- Access to a model Safe System Hierarchy of Control framework template, which is the same as that presented in Section 4.2.4.
- Discussion about the framework, informing practitioners about the approach and where it sits in the treatment of crash locations/road safety assessment process.
- Cross-linking case studies with other functions and information on the RSET website. This provides practitioners with more detailed information about crash types and treatment measures, including photographs, road user movement/definitions for coding accidents code diagrams, relative costs and treatment life; and provides this within the context of a site assessment using the framework.

The functionality embedded in the site permits a user to quickly and easily move to other areas of interest through hyperlinks and sidebar menus.

The RSET website previously permitted practitioners to submit information about treatments for inclusion as case studies as part of future updates of the website. Following the inclusion of the Safe System Hierarchy of Control framework information and case studies, practitioners are invited to complete an assessment and submit it for inclusion as a case study to illustrate application of the framework.

Access to the website is via www.engtoolkit.com.au. Information presented on the relevant pages of the site describe how the RSET operates to assess the benefit and functionality of the changes to incorporate the Safe System Hierarchy of Control assessment framework.

6. Review of Austroads Guides

A review of each of the Austroads Guides was undertaken to assess the relevance to local government practitioners and how the outcomes of this project may inform future updates and/or changes to improve the relevance for local road networks. Some suggested changes may be incorporated with relatively minor effort, while others may require a more complete review to ensure proper context and cross-referencing.

The Guides and Parts are listed in Table 6.1. Where recommendations to update a Guide or a particular Part are considered appropriate, this is indicated in Table 6.1 with a ✓ mark in the 'update suggested' column. If no update has been considered necessary, then this is indicated with a – mark.

Where more extensive changes or updates are required, these could be considered when each Guide and Part is due for a review.

Table 6.1: Austroads Guides and Parts reviewed for application of the Safe System approach to local roads

Austroads Guide	Part	Update suggested
Guide to Road Safety	GRS Part 1: Road Safety Overview (2013)	✓
	GRS Part 2: Road Safety Strategy and Evaluation (2008)	–
	GRS Part 3: Speed Limits and Speed Management (2008)	✓
	GRS Part 4: Local Government and Community Road Safety (2009)	✓
	GRS Part 5: Road Safety for Rural and Remote Areas (2006)	✓
	GRS Part 6: Road Safety Audit (2009)	✓
	GRS Part 7: Road Network Crash Risk Assessment and Management (2006)	✓
	GRS Part 8: Treatment of Crash Locations (2009)	✓
	GRS Part 9: Roadside Hazard Management (2008)	✓
Guide to Traffic Management	GTM Part 1: Introduction to Traffic Management (2015)	–
	GTM Part 2: Traffic Theory (2008)	–
	GTM Part 3: Traffic Studies and Analysis (2013)	–
	GTM Part 4: Network Management (2015)	–
	GTM Part 5: Road Management (2014)	✓
	GTM Part 6: Intersections, Interchanges and Crossings (2013)	✓
	GTM Part 7: Traffic Management in Activity Centres (2015)	✓
	GTM Part 8: Local Area Traffic Management (2008)	✓
	GTM Part 9: Traffic Operations (2014)	–
	GTM Part 10: Traffic Control and Communications Devices (2009)	–
	GTM Part 11: Parking (2008)	✓
	GTM Part 12: Traffic Impacts of Developments (2009)	✓
	GTM Part 13: Road Environment Safety (2015)	✓

Austroads Guide	Part	Update suggested
Guide to Road Design	GRD Part 1: Introduction to Road Design (2015)	–
	GRD Part 2: Design Considerations (2015)	✓
	GRD Part 3: Geometric Design (2010)	✓
	GRD Part 4: Intersections and Crossings (2009)	✓
	GRD Part 4A: Signalised and Unsignalised Intersections (2010)	✓
	GRD Part 4B: Roundabouts (2011)	✓
	GRD Part 4C: Interchanges (2009)	–
	GRD Part 5: Drainage – General and Hydrology Considerations (2013)	–
	GRD Part 5A: Drainage – Road Surface, Networks, Basins and Subsurface (2013)	✓
	GRD Part 5B: Drainage – Opens channels, Culverts and Floodways (2013)	✓
	GRD Part 6: Roadside Design, Safety and Barriers (2010)	✓
	GRD Part 6A: Pedestrian and Cyclist Paths (2009)	✓
	GRD Part 6B: Roadside Environment (2015)	–
	GRD Part 7: Geotechnical Investigation and Design (2008)	–
	GRD Part 8: Process and Documentation (2009)	–
Guide to Asset Management	GAM Part 1: Introduction (2009)	–
	GAM Part 2: Community and Stakeholder Requirements (2009)	✓
	GAM Part 3: Asset Strategies (2009)	✓
	GAM Part 4: Program Development and Implementation (2009)	✓
	GAM Part 5-set (2009)	–
	GAM Part 6: Bridge Performance (2009)	–
	GAM Part 7: Road-related Assets Performance (2009)	–
	GAM Part 8: Asset Valuation and Audit (2009)	–
Guide to Road Transport Planning	Comprising just one part (2009)	✓
Guide to Project Evaluation	GPE Part 1: Introduction to Project Evaluation (2015)	✓
	GPE Part 2: Project Evaluation Methodology (2015)	✓
	GPE Part 3: Models and Procedures (2015)	–
	GPE Part 4: Project Evaluation Data (2015)	–
	GPE Part 5: Impact on National and Regional Economies (2015)	–
	GPE Part 6: Distributional (Equity) Effects (2015)	–
	GPE Part 7: Post-completion Evaluation (2015)	–
	GPE Part 8: Examples (2015)	✓
Guide to Bridge Technology	GBT Part 1: Introduction and Bridge Performance (2012)	–
	GBT Part 2: Materials (2012)	–
	GBT Part 3: Typical Bridge Superstructures, Substructures and Components (2012)	–
	GBT Part 4: Design Procurement and Concept Design (2012)	–
	GBT Part 5: Structural Drafting (2012)	–
	GBT Part 6: Bridge Construction (2012)	–
	GBT Part 7: Maintenance and Management of Existing Bridges (2012)	–

Source: ARRB Group.

7. Conclusions

The road networks managed by local government in Australia and New Zealand are extensive and represent the majority of the length of public roads in both countries. However, they carry a significantly smaller proportion of the traffic volumes than the state road networks. Contributing to more than half of all casualties resulting from road crashes and between 40 and 46% of fatalities, the risk to drivers on local roads can be up to twice that faced on state roads. For this reason, addressing safety on local roads is important to achieving national targets for a sustained reduction in FSI crashes.

Analysis of crash data has identified the type and number of FSI crashes on local government-managed roads; those involving pedestrians are a clear priority issue needing attention. However, rural roads also present a challenge to local governments; crashes on these roads tend to be random events, are not in clusters, and for many rural and regional councils may occur at locations geographically removed from population centres.

For most councils, there may be significant hurdles to adopting upgrades of local road networks. A piecemeal, reactive approach to road safety issues can fail to address the underlying factors that contribute to crashes.

Responding effectively to local road safety issues requires local government practitioners to have a thorough understanding of the Safe System approach, and with this, an appreciation of the contribution and effectiveness of infrastructure-based treatments. Importantly, practitioners need to develop an appreciation of the interconnectedness of the Safe System pillars and the array of treatment options available under them. Such an appreciation will assist the engagement of all of a council's resources across each department to deal with local road safety issues.

The framework developed through this project has been designed to assist practitioners to assess local road safety concerns within the context of the Safe System approach. It has been prepared for application by technical and non-technical people within council and encourages consideration of not just the road infrastructure options, but also measures that can improve road user behaviour and training and awareness; it encourages consideration of measures relating to vehicles as well.

The primary purpose of the project was the development of a greater understanding of Safe System principles by practitioners, and subsequently, an increased application of the Safe System approach on locally-controlled roads. To assist council staff, the case study examples of the framework have been added to the web-based Road Safety Engineering Toolkit (www.engtoolkit.com.au). This site provides information about factors contributing to road crashes, treatment options available to address them, and a framework for evaluating local issues.

By taking into account all of the outputs of this project, local government will be better able to adopt best practice in many areas of road management, and make valuable incremental improvements towards achieving a Safe System.

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Appendix A Treatment Summary Tables

A.1 Description of Treatment Summary Tables

The tables currently group treatments based on issue/deficiency, as follows:

1. Median treatment options
2. Run-off-road treatment options
3. Mid-block speed treatment options
4. Major intersection treatment options
5. Major intersection turning treatments
6. Minor intersection treatment options
7. Minor intersection turning treatments
8. Pedestrian treatments
9. Cyclist treatments
10. Treatments for speeding at intersections
11. Activity centre treatments
12. Transitional treatments
13. Road maintenance treatments and activities.

The tables also indicate:

- Classification:
  - Primary – Primary Safe System infrastructure/treatments may be considered to be those that have the potential to deliver near zero death and serious injury. Many primary treatments are high-cost, and local governments may not be in a financial position to always implement such treatments.
  - Supporting – Supporting treatments generally provide incremental improvements towards achieving a Safe System. These are usually at a lower cost than Safe System treatments, but it will generally take multiple incremental treatments to reach the equivalent crash reduction.
- Type of treatment:
  - Delineation – Treatment aims to improve delineation for road users so that they stay on the roadway, choose the correct line through corners and take care when approaching hazards.
  - Separation – In this category, the treatment aims to reduce the likelihood of road user conflicts by separating their movements in time and/or space.
  - Speed Reduction – Treatment aims to reduce the speed of drivers through road infrastructure, signage or perceptual measures. Bringing vehicle speeds down to Safe System levels can subsequently lead to a reduction in the number and severity of crashes.
  - Enforcement – Treatment that influences driver behaviour by enforcing road rules. Generally, involves the use of fines and penalties for offending drivers.
  - Efficiency – The primary goal of the treatment is to improve the efficiency, amenity or congestion on the route or network, with possible safety effects as a result.
  - Roadside – Treatments that aim to reduce the incidence or severity of run-off-road crashes.
  - Combination – Treatment involves a combination of the above.
  - Night-time – Treatment that aims to reduce incidence of night-time crashes. These may also involve treatments of the above types.

- Expected costs:
  - projects with capital costs < $50 000 = low cost ($)
  - projects with capital costs between $50 000 and $250 000 = medium cost ($$)
  - projects with capital costs > $250 000 = high cost ($$$).

A.2 Treatment Options Summary Table

Table A 1: Summary of median treatment options

Treatments		Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Primary	Wide median with flexible barrier	Separation	Rural/urban	$$$		✓			
	Wide median (constructed)	Delineation/ separation	Urban/rural	$$$		✓			
	Narrow flush median (wide centreline) with barrier	Delineation/ separation & speed reduction	Urban/rural	$$$		✓			
Supporting	Narrow flush median (wide centreline) with audio-tactile devices	Delineation/ separation	Urban/rural	$$$		✓			
	Narrow flush median (wide centreline)	Delineation/ separation	Urban/rural	$$$		✓			
	Rubber lane marker	Delineation	Urban	$$		✓			
	Centreline with delineator posts	Delineation	Urban	$$		✓			
	Profile centreline	Delineation	Urban/rural	$$		✓			
	Painted centreline	Delineation	Urban/rural	$		✓			
	Glow in the dark road markings	Delineation	Urban/rural	$$		✓			✓
	Safe hit median posts	Delineation	Urban/rural	$		✓			

Source: ARRB Group.

Table A 2: Summary of run-off-road treatment options

Treatment		Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Primary	Appropriate clear zone and flexible roadside barriers	Roadside	Rural/urban	$$$		✓			
	Roadside hazard barriers	Roadside	Rural/urban	$$		✓			
Supporting	Sealed shoulders	Roadside	Rural	$$		✓			
	Chevron alignment markers	Delineation	Rural	$		✓			
	Guide posts	Delineation	Rural	$		✓			
	Profile edgeline	Delineation	Rural/urban	$$		✓			
	Painted edgeline	Delineation	Rural/urban	$		✓			
	Transverse line markings	Speed reduction	Rural/urban	$		✓			
	Glow in the dark road markings	Delineation	Urban/rural	$		✓			✓
	SLOW markings	Speed reduction	Rural	$		✓			
	Advanced curve warning signs	Speed reduction	Rural/urban	$$		✓			
	Vehicle activated warning signs (on curve approaches)	Speed reduction	Rural/urban	$$		✓			✓

Source: ARRB Group.

Table A 3: Summary of mid-block speed treatment options

Treatment		Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Supporting	Slow points	Speed reduction	Urban	$$	✓	✓			
	Speed humps/road cushions	Speed reduction	Urban	$$	✓	✓			
	Wombat crossings	Speed reduction	Urban	$$	✓	✓			
	Road diets	Combination	Urban	$$	✓	✓			
	Centre blister islands	Speed reduction	Urban	$$	✓	✓			
	Kerb extensions	Speed reduction	Urban	$$	✓	✓			
	Pedestrian refuge islands	Speed reduction/ separation	Urban	$$	✓	✓			
	Lane narrowing	Speed reduction	Urban	$$	✓	✓			
	Repeater signs	Speed reduction	Urban	$	✓	✓			
	Optical speed bars	Speed reduction	Urban/rural	$	✓	✓			✓
	Parallelogram-shaped pavement markers	Speed reduction	Urban/rural	$	✓	✓			✓
	Transverse line marking on approach to potential hazard	Speed reduction	Urban/rural	$	✓	✓			
	Decrease in speed limit: • unrestricted to a speed limit • 100–80 km/h • 80–60 km/h • 60–50 km/h	Speed reduction	Urban/rural	$	✓	✓			

Source: ARRB Group.

Table A 4: Summary of major intersection treatment options

Treatment		Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Primary	Grade separation: X-intersection T-Intersection	Separation	Urban/rural	$$$		✓			
	Installing roundabout	Speed reduction/ severity	Urban/rural	$$$	✓	✓			
	Signalising intersection	Separation/ efficiency	Urban/rural	$$$	✓	✓			
Supporting	Speed cameras	Enforcement	Urban/rural	$$	✓	✓			
	Red light cameras	Enforcement	Urban	$$	✓	✓			
	Linked signals	Efficiency	Urban	$	✓	✓			
	Intersection platforms	Speed reduction	Urban	$$	✓	✓			
	Transverse rumble strips	Speed reduction	Urban/rural	$	✓	✓			
	Lighting (new)	Night-time	Urban/rural	$$	✓	✓			
	Lighting (upgrade)	Night-time	Urban/rural	$$	✓	✓			
	All red time extension	Separation	Urban	$	✓	✓			
	Advanced intersection warning sign	Speed reduction	Urban/rural	$	✓	✓			
	Vehicle activated warning signs	Speed reduction	Rural/urban	$$	✓	✓			

Source: ARRB Group.

Table A 5: Summary of major intersection turning treatments

Treatment		Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Supporting	Turn restrictions	Separation	Urban	$		✓			
	Right-turn – median U-Turn	Separation/ efficiency	Urban	$		✓			
	Offset right-turn lane	Separation/ efficiency	Urban	$		✓			
	Extended right-turn lane	Separation/ efficiency	Urban	$		✓			
	Painted turning lanes	Separation/ efficiency	Urban	$		✓			

Source: ARRB Group.

Table A 6: Summary of minor intersection treatment options

	Treatment	Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Primary	Installing local road roundabout	Speed reduction/ severity	Urban	$$	✓	✓			
Supporting	Installing roundabout (mini)	Severity	Urban	$	✓	✓			
	Raised intersections	Speed reduction	Urban	$$	✓	✓			
	Kerb extensions	Speed reduction	Urban	$$	✓	✓			
	Lane narrowing	Speed reduction	Urban	$$	✓	✓			
	Transverse rumble strips	Speed reduction	Urban/rural	$	✓	✓			
	Painted intersection	Speed reduction	Urban/rural	$	✓	✓			
	Optical speed bars	Speed reduction	Urban/rural	$	✓	✓			✓
	Lighting (new)	Night-time	Urban/rural	$$$	✓	✓			
	Lighting (upgrade)	Night-time	Urban/rural	$$	✓	✓			

Source: ARRB Group.

Table A 7: Summary of minor intersection turning treatments

	Treatment	Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Primary	Road closure	Separation	Urban	$$$		✓			
Supporting	Turn restrictions	Separation	Urban	$$		✓			
	Restrict access points	Separation	Urban	$$		✓			

Source: ARRB Group.

Table A 8: Summary of pedestrian treatments

	Treatment	Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Supporting	Pedestrian refuge islands	Separation/ speed reduction	Urban	$$	✓	✓			
	Pedestrian fences	Separation	Urban	$		✓			
	Wombat crossing	Speed reduction	Urban	$$	✓	✓			
	Puffin crossing	Efficiency	Urban	$$		✓			
	Marked pedestrian crossings	Speed reduction	Urban	$	✓	✓			
	Lighting	Night-time	Urban	$$	✓	✓			
	Parallelogram-shaped pavement markings	Speed reduction	Urban/rural	$	✓	✓			✓

Source: ARRB Group.

Table A 9: Summary of cyclist treatments

	Treatment	Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Primary	Dedicated off-road cycle lane	Separation	Urban/rural	$$$		✓			
	Off-road shared path	Separation	Urban/rural	$$$		✓			
	Copenhagen style cycle lane	Separation	Urban	$$$		✓			✓
	Kerbside cycle lane	Separation	Urban	$$		✓			
	Cycle friendly C-Roundabout	Separation/ Speed reduction	Urban	$$$		✓			✓
	Hybrid cycle track	Separation	Urban	$$		✓			✓
	Segregation using planters, wands and armadillos	Separation	Urban	$$		✓			✓
Supporting	Cycle lane with narrow painted median	Separation	Urban	$		✓			
	Cycle lane with narrow lane separators	Separation	Urban	$$		✓			
	Painted cycle lane	Separation	Urban/rural	$		✓			
	Wide kerbside lane	Separation	Urban/rural	$$		✓			
	Advanced stop line/early green phase	Separation	Urban	$		✓			✓
	Road diets	Combination	Urban	$$		✓			✓
	Two-stage right-turn at intersections	Combination	Urban	$		✓			✓

Source: ARRB Group.

Table A 10: Summary of treatments for reducing speeds at intersections

	Treatment	Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Primary	Installing roundabout	Speed reduction/ severity	Urban/rural	$$$	✓	✓			
Supporting	Speed cameras	Enforcement	Urban/rural	$$	✓	✓			
	Intersection raised platforms	Speed reduction	Urban	$$	✓	✓			
	Turn to red if speeding	Enforcement/ speed reduction	Urban/rural	$	✓	✓			✓
	Rest-on-Red	Separation/ speed reduction	Urban	$	✓	✓			✓
	Transverse rumble strips	Speed reduction	Urban/rural	$	✓	✓	✓		✓
	Restriction of sight distance	Speed reduction	Urban/rural	$	✓	✓			✓
	Decrease in speed limit: unrestricted to a speed limit 100–80 km/h 80–60 km/h 60–50 km/h	Speed reduction	Urban/rural	$	✓	✓	✓		

Source: ARRB Group.

Table A 11: Summary of activity centre treatments

	Treatment	Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Primary	Shared spaces	Speed reduction	Urban	$$$	✓	✓			
Supporting	School zone	Combination	Urban	$	✓	✓			
	Kerb extensions	Speed reduction	Urban	$$	✓	✓			
	Rest-on-Red	Separation/ speed reduction	Urban	$	✓	✓			
	Speed humps	Speed reduction	Urban	$	✓	✓			
	Advisory speed signage	Speed reduction	Urban/rural	$	✓	✓			
	Decrease in speed limit: 60–50 km/h	Speed reduction	Urban	$	✓	✓			
	Variable message sign	Efficiency/ speed reduction	Urban/rural	$$	✓	✓			
	Lighting: pedestrians intersections	Night-time	Urban	$$	✓	✓			

Source: ARRB Group.

Table A 12: Summary of transitional treatments

Treatment		Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Supporting	Gateway treatments	Speed reduction	Urban/rural	$	✓	✓			
	Transition buffer zones	Speed reduction	Urban/rural	$	✓	✓			
	Variable message signs	Efficiency/speed reduction	Urban/rural	$$	✓	✓			
	Advisory speed signage	Speed reduction	Urban/rural	$	✓	✓			
	Advanced warning signs for speed limit change	Speed reduction	Rural/urban	$	✓	✓			

Source: ARRB Group.

Table A 13: Summary of maintenance type treatments and activities that may contribute to road safety

Treatment		Type	Road environment	Expected costs	Safe speeds	Safe roads and roadsides	Safe road users	Safe vehicles	Innovative (new concept in Australia)
Supporting	Resealing to improve skid resistance		Urban/rural	$		✓			
	Maintenance of roadside vegetation	Roadside	Urban/rural	$		✓			
	Edge drop removal	Roadside	Urban/rural	$		✓			
	Maintenance of signs, delineation and pavement marking, including improved conspicuity	Delineation	Urban/rural	$		✓			
	Drainage improvements	Roadside	Urban/rural	$		✓			

Source: ARRB Group.

Appendix B Case Study Examples of the Safe System Hierarchy of Control

B.1 Town Centre Pedestrian/Vehicle Safety

B.1.1 Site Description, Risk Factors and Safe System Pillar Analysis

Site description	
Main Street in the semi-rural Small Town centre services a medium-sized commercial/business/shopping precinct. Main Street is a divided carriageway with 2 x traffic lanes and 1 x kerbside parking lane in each direction. The carriageways are separated by a landscaped central median. The sign posted speed limit is 50 km/h, although the 85th percentile speed is approximately 40 km/h. The subject section of Main Street is approximately 200 m in length and bounded on either end by roundabout-controlled intersections. There is a marked pedestrian crossing midway along the length of this section of Main Street. Council is considering an upgrade to this section to deal with pedestrian safety and amenity concerns. There is a significant pedestrian demand using the mid-block zebra crossing, which disrupts traffic flow. Kerbside parking along the length of Main Street has a 1-hour parking time limit, with the exception of 15 minutes parking adjacent the post office building. The frequent turnover of parking spaces was observed to cause a disruption to traffic flow along Main Street.	
Crash risk identification	
Recorded crash history – last five years (2010–14): • crash type – 3 x RUM 00, 2 x RUM 02, 4 x RUM 30, 1 x RUM 34, 2 x RUM 42 • crash severity – 4 x FSI, 2 x MI, 9 x PDO. Pedestrian crashes: • pedestrians may be hidden from view of approaching drivers by high-sided vehicles in roadside parking • the crossing extends across the landscaped median island – drivers may fail to observe a pedestrian approaching from the adjacent carriageway (note – landscaping does not obscure or block lines of sight for drivers and pedestrians) • vehicles may be travelling too fast on approach to the crossing, reducing the ability to stop for pedestrians on or entering the crossing, and increasing the severity of crashes. Rear-end: • short-term car parking may lead to an increased occurrence of rear-end type conflicts • the crossing point has an unregulated and high demand. This contributes to traffic disruption and congestion along Main Street • vehicles may be travelling too fast along Main Street, resulting in drivers unable to respond to changing traffic, particularly approaching the pedestrian crossing location.	
Safe System pillar analysis	
Safe roads • short-term on-street parking means that rear-end collision conflicts may be occurrences that are more regular • the crossing point has an unregulated and high demand. This contributes to traffic disruption and congestion along Main Street • pedestrians may be hidden from view of approaching drivers by high-sided vehicles.	Safe people • pedestrians failing to ensure their visibility to approaching drivers prior to crossing • drivers failing to observe pedestrians approaching from the road median due to focus on pedestrians approaching from footpath.
Safe speeds • 50 km/h speed limit and the 85th percentile speed are higher than Safe System objectives for pedestrian FSI risk • vehicles may be travelling too fast for the conditions.	Safe vehicles • vehicles involved tend to be SUVs, 4WDs and older light vehicles that lack pedestrian impact safety features.

Source: ARRB Group.

Site photographs

Source: Aerial photograph – © nearmap (2015), 'New South Wales', map data, nearmap, Sydney, NSW. Photographs – ARRB Group.

B.1.2 Safe System Hierarchy of Control Assessment

Crash type	Cause/Hazard	Control method	Safe System pillars			
			Safe roads	Safe speeds	Safe people	Safe vehicles
Remove the risk						
Vehicle-pedestrian collisions on the marked pedestrian crossing	Pedestrians crossing vehicle path, i.e. sharing same space and time	Remove the at-grade pedestrian crossing and close pedestrian access	✓		✓	
		Replace the at-grade pedestrian crossing with a grade separated crossing	✓		✓	
Rear-end (and other type) crashes	High turnover of short-term parking	Remove all on street car parking	✓		✓	

<table>
<tr><th rowspan="2">Crash type</th><th rowspan="2">Cause/Hazard</th><th rowspan="2">Control method</th><th colspan="4">Safe System pillars</th></tr>
<tr><th>Safe roads</th><th>Safe speeds</th><th>Safe people</th><th>Safe vehicles</th></tr>
<tr><td colspan="7">Reduce the risk</td></tr>
<tr><td rowspan="3">Vehicle-pedestrian collisions on the marked pedestrian crossing</td><td>Pedestrians crossing vehicle path, i.e. sharing same space and time</td><td>Signalise the pedestrian crossing – preferably as a ‘pelican crossing’</td><td>✓</td><td>✓</td><td>✓</td><td></td></tr>
<tr><td>Obstruction from high vehicles</td><td>Convert zebra crossing to wombat crossing to improve the visibility of pedestrians on the crossing</td><td>✓</td><td>✓</td><td></td><td></td></tr>
<tr><td>Insufficient time to stop for pedestrians</td><td>Provide other traffic calming measures such as a raised platform/tactile device to slow traffic on approach to the pedestrian crossing</td><td>✓</td><td>✓</td><td>✓</td><td></td></tr>
<tr><td rowspan="4">Rear-end (and other type) crashes</td><td rowspan="2">High turnover of short-term parking</td><td>Extend the time periods for on-street car parking</td><td>✓</td><td></td><td>✓</td><td></td></tr>
<tr><td>Increase separation distance between kerbside parking lane and adjacent traffic lane</td><td>✓</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Sudden stopping due to pedestrian crossing, vehicle parking, etc.</td><td>Provide additional traffic calming measures, e.g. convert the zebra crossing to a wombat crossing or introduce a raised platform/tactile device to slow traffic on approach to the pedestrian crossing</td><td>✓</td><td>✓</td><td>✓</td><td></td></tr>
<tr><td>Promote 5-star ANCAP-rated vehicles with crash avoidance technology (ESC, ABS, AEB)</td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td colspan="7">Change road user behaviour</td></tr>
<tr><td rowspan="2">Vehicle-pedestrian collisions on the marked pedestrian crossing</td><td>Obstruction from high vehicles</td><td>Provide signage reminding drivers not to overtake on crossing approaches</td><td>✓</td><td></td><td>✓</td><td></td></tr>
<tr><td>Vehicles travelling too fast for the conditions</td><td>Reduce speed limit to meet Safe System FSI objectives for pedestrians (i.e. impact speeds ≤ 30 km/h)</td><td>✓</td><td>✓</td><td>✓</td><td></td></tr>
<tr><td>Rear-end (and other type) of vehicle-vehicle crashes</td><td>Vehicles travelling too fast for the conditions</td><td>Provide additional warning signage</td><td>✓</td><td></td><td>✓</td><td></td></tr>
<tr><td colspan="7">Protect the road user</td></tr>
<tr><td>Vehicle-pedestrian collisions on the marked pedestrian crossing</td><td>Obstruction from high vehicles
Vehicles travelling too fast for the conditions</td><td rowspan="2">Promote 5-star ANCAP-rated vehicles with pedestrian detection and protection measures</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">✓</td></tr>
<tr><td>Rear-end (and other type) crashes</td><td>Sudden stopping due to pedestrian crossing, vehicle parking, etc.
Vehicles travelling too fast for the conditions</td></tr>
</table>

Source: ARRB Group.

B.2 Urban Roundabout Bicycle/Vehicle Safety

B.2.1 Site Description, Risk Factors and Safe System Pillar Analysis

Site description

Local Street, Urbantown is a residential road in an urban area. It meets Community Street at a roundabout intersection. Both roads feature a 40 km/h speed limit.

Local Street is a divided carriageway formation with one travel lane in each direction and parallel kerbside parking. It forms part of a cycle route and features on-road cycle lanes marked between the traffic lane and kerbside parking spaces.

Community Street is an undivided carriageway formation; there are no bicycle lanes, but there is angled, nose-to-kerb parking.

The roundabout is a slightly elliptical-shaped and the splitter islands in Community Street are painted line marking.

The line marking is in a fair to poor condition. There is landscape planting in the roundabout centre island.

There are local primary schools located both north (~350 m) and south (~1.3 km) of the intersection, along Community Street.

Problem definition

There have been eight crashes recorded in the five-year period 2009–13, all of which have involved pedal cyclists.

Site observations indicated that cyclists appear to not slow down when entering and exiting the roundabout.

The marked cycle lanes end at the roundabout give-way line, meaning they enter to the left of vehicles entering the roundabout. This positioning of the cyclists may lead to them not being noticed by other drivers looking to give way to entering and circulating traffic.

The presence of large trees in Community Street partially impedes intervisibility for road users and casts shadows on the roundabout; vegetation in the roundabout partially obscures circulatory traffic. The effect of the trees and vegetation may be more significant in obscuring cyclists than other vehicles.

Although not involved in recorded crashes, there are power poles located close to the edge of the carriageway that will increase crash severities if impacted.

The path through the roundabout north to south has a tighter road layout than for east to west due to the elliptical design of the centre island.

Crash risk identification

Recorded crash history:

- there have been eight crashes recorded in the five-year period 2009–13, all of which have involved pedal cyclists.

Factors at the site contributing to cyclist crashes include:

- drivers failing to identify/give way to cyclists
- trees impeding visibility and street lighting
- vegetation on roundabout impeding visibility to cyclists on the roundabout
- limited deflection of roundabout may not reduce speeds to Safe System limits
- provision for cyclists on roundabout is lacking
- entry speeds onto the roundabout could be slightly high, particularly for cyclists.

Safe System pillar analysis

Safe roads • trees impeding visibility and street lighting • vegetation on roundabout impeding visibility to cyclists on the roundabout • limited deflection of roundabout • provision for cyclists on roundabout is lacking.	Safe people • drivers failing to identify/give way to cyclists • cyclists fail to reduce speed when entering the roundabout.
Safe speeds • entry speeds onto the roundabout tend to be too high for the restricted visibility provided.	Safe vehicles

Source: ARRB Group

Site photographs

Source: Aerial photograph – ©nearmap (2015), 'Victoria', map data, nearmap, Sydney, NSW. Photographs – Google Earth (2014), 'Victoria', map data, Google, California, USA.

B.2.2 Safe System Hierarchy of Control Assessment

Crash type	Cause/Hazard	Control method	Safe System pillars			
			Safe roads	Safe speeds	Safe people	Safe vehicles
Remove the risk						
Cyclist crashes	Drivers failing to identify/give way to cyclists	Provide separate cyclist path with grade separated crossings.	✓			
Reduce the risk						
Cyclist crashes	Drivers failing to identify/give way to cyclists	Provide a cycle path on Community Road so drivers on this road are already aware of cyclist presence.	✓			
	Drivers failing to identify/give way to cyclists Poor provision for cyclists on roundabout	Merge cyclists with general traffic prior to roundabout so they enter roundabout in line with vehicle flow rather than to side of vehicle flow.	✓		✓	
	Trees impeding visibility and street lighting	Remove, trim or thin trees to improve visibility.	✓		✓	
	Vegetation on roundabout impeding visibility to cyclists on the roundabout	Remove vegetation from roundabout island above, say 0.5 m height, to improve visibility.	✓		✓	
	Entry speeds onto the roundabout appear high	Provide physical measure to narrow traffic lanes, e.g. kerbing of cycleway. Install speed platforms on approach to the roundabout. Improve deflection of roundabout either through the roundabout or on approach (chicanes). Convert the roundabout to a raised intersection treatment.	✓	✓	✓	
Change road user behaviour						
Cyclist crashes	Drivers failing to identify/give way to cyclists Poor provision for cyclists on roundabout	Enhance the cyclist path pavement markings and install warning signs on roundabout and all approaches.	✓		✓	
	Trees impeding visibility and street lighting	Regularly trim vegetation to maintain visibility.	✓		✓	
	Vegetation on roundabout impeding visibility to cyclists on the roundabout	Regularly trim hedge on roundabout to maintain visibility.	✓		✓	
	Drivers failing to identify/give way to cyclists	Improve visibility/prominence of the on-road cycleway paths. Enhance bicycle path stencils. Provide cyclist warning signs on approach to the roundabout.	✓	✓	✓	
		Promote vehicles with crash avoidance technology (ESC, ABS, AEB).	✓		✓	✓
	Cyclists not obeying road rules	Improve enforcement of cyclist behaviour. Provide signing to encourage cyclists to obey road rules. Provide cyclist education/information to encourage compliance and responsible riding.	✓	✓	✓	
	Entry speeds onto the roundabout appear high	Include warning signs to encourage both drivers and cyclists to reduce	✓	✓	✓	

Crash type	Cause/Hazard	Control method	Safe System pillars			
			Safe roads	Safe speeds	Safe people	Safe vehicles
		speeds on approach and through the roundabout.				
		Engage a road safety officer to educate students in nearby schools on safe cycling.			✓	
Protect the road user						
Cyclist crashes	Drivers failing to identify/give way to cyclists	Promote 5-star ANCAP rated vehicles with pedestrian protection.			✓	✓
		Promote the use of high-visibility clothing and lighting for cyclists.			✓	✓

Source: ARRB Group.

B.3 Rural Road Safety

B.3.1 Site Description, Risk Factors and Safe System Pillar Analysis

Site description	
Country Road, is a rural, single carriageway road, approximately 9 km in length, bounded by regional highways on either end. The section of road in question is a 1 km straight section located between two local roads. Country Road services rural and rural residential areas and a school bus service uses the road to transport local children into the town school. The posted speed limit is 100 km/h. The ride quality on the road is poor and can only be comfortable driven at 70–80 km/h. The road surface is visible undulating. There are large mature trees and utility service poles located along the road verge area. There is a formed unsealed gravel shoulder, a marked centreline but no edgelines. Guide posts are present; raised reflective pavement markers are intermittent, with many missing or damaged.	
Problem description	
There have been three serious injury crashes, seven other injury crashes (in the period of 2009–14). These have all been loss-of-control crashes(run-off-road and head-on) attributed to: • fatigue • animals on the road • driver error type. The road width is very narrow, without traversable shoulders, limiting a driver's ability to regain control of an errant vehicle. Loss-of-control crashes have also resulted in run-off-road into object crashes due to hazards in the clear zone.	
Crash risk identification	
Recorded crash history – last five years (2010–14): • ten injury crashes (three serious injury) • all loss-of-control • attributed to fatigue, avoidance of animals on the road and driver error. Loss of control: • fatigued driving • distracted driving • poor road surface makes it difficult for driver to regain control of errant vehicle • narrow road with no shoulder does not give a driver the opportunity to regain control of their vehicle • swerving to avoid animals on the road • driver error. Run-off-road into object: • roadside hazards such as trees, culverts and poles located in the clear zone • 100 km/h speed zone higher than Safe System objectives for run-off-road into object FSI risk.	
Safe System pillar analysis	
Safe roads • hazards within clear zone • poor road surface • poor road geometry • animals on the road.	Safe people • fatigued driving • distracted driving • driver error.
Safe speeds • speed limit not consistent with Safe System human tolerance levels.	Safe vehicles

Source: ARRB Group.

Site photographs

Source: Aerial photograph – ©nearmap (2015), 'Victoria', map data, nearmap, Sydney, NSW. Photographs – ARRB Group.

B.3.2 Safe System Hierarchy of Control Assessment

Crash type	Cause/hazard	Control method	Safe System pillars			
			Safe roads	Safe speeds	Safe people	Safe vehicles
Remove the risk						
Run-off-road into object	Hazards within clear zone	Remove hazards from clear zone.	✓			
Reduce the risk						
Run-off-road into object	Hazards within clear zone	Provide roadside barriers.	✓			
Loss-of-control crashes	Poor road geometry	Widen road widths and provide traversable road shoulder to enable drivers to regain control of errant vehicles.	✓			
	Poor road surface	Provide road surface to current standard to provide drivers greater control of their vehicle.	✓			
	Animals on the road	Provide deterrents such as scents and odours to deter animals from roadway. Provide fencing for length of intrusion to prevent animals entering roadway.	✓			
	Poor road geometry Animals on the road Driver error	Provide roadside lighting to improve nighttime visibility of roadway, illumination of any animals, and guide drivers along roadway.	✓		✓	
		Promote vehicles with crash avoidance technology (ESC, ABS, AEB).			✓	✓
	Driver error	Improve delineation of road to better guide drivers.	✓		✓	
Change road user behaviour						
Loss-of-control crashes	Poor road surface	Warning signage including VAS to encourage drivers to take greater caution whilst driving.	✓	✓	✓	
		Reduce speed limit to provide drivers more opportunity to regain control of errant vehicle.		✓		
	Animals on the road	Warning signage including animal activated signage.	✓	✓	✓	
Run-off-road into object	Hazards within clear zone Speed limit inconsistent with human tolerance thresholds	Reduce speed limit to meet Safe System FSI objected for run-off-road into roadside hazards (i.e. impact speeds ≤ 40 km/h).			✓	
Protect road user						
Loss-of-control crashes	Poor road geometry Poor road surface Animals on the road	Promote 5-star ANCAP rated vehicles that improve the survivability of crashes compared to lower rated vehicles.			✓	✓
Run-off-road into object	Hazards like trees culverts, poles in the clear zone					

Source: ARRB Group.

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