Guide to Traffic Management Part 13

Road Environment Safety

Austroads

Guide to Traffic Management Part 13: Road Environment Safety

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Guide to Traffic Management Part 13: Road Safety Environment

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Abstract

The Guide to Traffic Management has 13 parts and provides comprehensive coverage of traffic management guidance for practitioners involved in traffic engineering, road design, town planning and road safety.

Part 13: Road Environment Safety is concerned with traffic management practice under the Safe System philosophy. The Guide emphasises the need for the road system to provide an environment which assists road users to behave effectively and safely. It considers the role of traffic management in influencing road user behaviour, and provides guidance for practitioners specifically on road safety aspects of traffic management.

Part 13 defines a safe road environment and the broad approaches for achieving it. It outlines basic human factors as related to users of the road and traffic environment, and how these can be influenced by road design and traffic management practice. It also describes the basic components of road safety engineering and its application in terms of risk engineering concepts, primary strategies and safety management systems, and outlines the principles and practice of managing safety in the road environment, as related to road infrastructure features and the basic tools of traffic engineering and management.

Keywords

Road environment safety, road safety, Safe System, human factors, traffic management, driver behaviour, road safety engineering, road alignment, cross-section, pavement, roadside, intersections, crossings, traffic controls, signals, signs, delineation, lighting, roadworks.

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This edition includes updated Safe System contents in Section 3. Discussion on driver workload is provided in Section 4.5. Section 5.2 is updated based on the latest Austroads research findings regarding aligning the management of the elements with a Safe System. Appendix A is revised to provide guidance on the linkage to other Parts of the Guides and Standards.

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Austroads

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:

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- Roads Corporation Victoria
- Queensland Department of Transport and Main Roads
- Main Roads Western Australia
- Department of Planning, Transport and Infrastructure South Australia
- Department of State Growth Tasmania
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1. Introduction

1.1 Purpose and Scope

The purpose of *Part 13* of the *Guide to Traffic Management* is to provide the underlying philosophy of a safe road environment as it relates to traffic management practice, and to place this in the context of relevant guidance provided in other Austroads Guides. This Part is not intended as a comprehensive document but forms a useful link between the *Guide to Traffic Management* and other Guides, particularly the *Guide to Road Safety* and the *Guide to Road Design*.

The primary focus of this Part is on traffic management and traffic engineering, and the expected audience also includes road planners and designers who share responsibility for safety aspects of their practice with traffic engineers. These road safety engineering practitioners play a fundamental role in achieving a safer road environment. They will be most effective when their road agencies encourage a focussed approach to road safety engineering. This Guide will therefore also be a useful reference for senior managers in road agencies.

Part 13 of the *Guide to Traffic Management* has the title *Road Environment Safety* to define the extent of its scope within the contexts of:

- the thirteen different parts of the *Guide to Traffic Management*
- other Guides in the range of Austroads publications.

The structure and content of the Guide is outlined in *Part 1: Introduction to Traffic Management*. The thirteen parts are summarised in Table 1.1.

Part 13 provides information and guidance for practitioners specifically in relation to road safety aspects of traffic management in the road environment. It considers the role of traffic management in influencing road user behaviour, and in improving safety in the road, traffic, and the roadside environment.

1.2 Link to National Road Safety Strategies

Both Australia and New Zealand have strategies to deal with road safety. Australia has its National Road Safety Strategy 2011–2020 (Australian Transport Council 2011) and corresponding action plans (Department of Infrastructure and Regional Development 2015) while New Zealand has its Strategy 2010–2020: the Safer Journeys Strategy (Ministry of Transport 2014).

These strategies have helped drive Australia and New Zealand to improve road safety to address the number of road users killed and seriously injured on Australian and New Zealand roads.

The cornerstone of the Australian and New Zealand road safety strategies is the Safe System approach. This is described in further detail in Section 2. To ensure that the Safe System elements are considered and measured, the Safe System Assessment Framework (Austroads 2016a) guides the user on how to assess how well a given project aligns with Safe System principles. For further information refer to Section 4.4.

Table 1.1: Parts of the Guide to Traffic Management

Part	Title	Content
Part 1	Introduction to Traffic Management	• Introduction to the discipline of traffic management. • Breadth of the subject and the relationship between the various Parts of the Guide.
Part 2	Traffic Theory	• An introduction to the characteristics of traffic flow and the theories, models and statistical distributions used to describe many traffic phenomena. • Processes that practitioners should consider.
Part 3	Traffic Studies and Analysis	• Traffic and transport data collection surveys and studies. • Traffic analysis for mid-block situations (including freeways/motorways). • Analysis of signalised and unsignalised intersections, including roundabouts.
Part 4	Network Management	• Broad strategies and objectives of managing road networks to provide effective traffic management for all road users. • Network needs for heavy vehicles, public transport users, pedestrians, cyclists and private motor vehicles. • Guidance on transport networks and network operation planning.
Part 5	Road Management	• Guidance on managing mid-block traffic conditions. • Good practice for access management, allocation of space to various road users, and lane management. • Application of speed limits.
Part 6	Intersections, Interchanges and Crossings	• Types of intersection and selection of intersection type. • Appropriate use and design of various intersection types. • Traffic management issues and treatments for intersections, interchanges and other crossings.
Part 7	Traffic Management in Activity Centres	• Principles for planning the management of traffic in activity centres and associated transport nodes. • Techniques for traffic management in activity centres. • Examples and key considerations for various types of centres.
Part 8	Local Area Traffic Management	• Planning and management of road space at a local area. • Guidance on selection, design, application and effectiveness of traffic control measures on an area wide or at least whole-of-street basis.
Part 9	Traffic Operations	• Applications used in traffic operations. • System configuration and operation guidance. • Current practice for common systems including network monitoring, traffic signals, congestion management, incident management, freeway/motorway management and traveller information. • Related systems integration and interoperability issues.
Part 10	Traffic Control and Communication Devices	• Signing and marking schemes. • Traffic signs, static and electronic. • Pavement markings and delineation. • Traffic signals and islands.
Part 11	Parking	• Parking policy. • Demand and supply. • On-street and off-street parking. • Parking guidance and control devices.
Part 12	Traffic Impacts of Developments	• Guidance on the need and criteria for impact assessment. • Detailed procedure for identifying and assessing the traffic impacts and mitigating their effects. • Assessment of safety, infrastructure and environmental effects.
Part 13	Road Environment Safety	• Principles and management of the safety of road environments within a traffic management context. • Links to relevant sections of the Guide to Road Design and Guide to Road Safety.

1.3 Link to Safe System

Across Australia and New Zealand, approaches to improving road safety continue to be guided by the principles of the Safe System, which is discussed in Section 2. People using the road network will make mistakes and therefore the whole system needs to be more forgiving of those errors. The Safe System focuses on roads, speeds, vehicles and road user behaviour as well as a range of associated activities, including performance monitoring and reporting. A Safe System ensures that the forces in collisions do not exceed the limits of human tolerance (Australian Transport Council 2011).

Making the road transport system more forgiving involves road safety engineering. The outcome is a safer road environment. The term road environment safety refers generally to the concept of safer roads and road-related areas.

To achieve a safe road environment in line with the Safe System, road agencies are moving towards safe mobility, this is reflected in the *Guide to Traffic Management* series. This is done to enable the clarification of the function and role of different segments of road for different segments of time and enables practitioners to understand the safety level of service (LOS) for various users of that segment of road, for a particular time and how to interact with it safely as intended. The *Guide to Traffic Management Part 5* (Austroads 2017e) and the *Guide to Traffic Management Part 6* (Austroads 2017f) provide guidance to practitioners on the management of roads from the mid-block and intersection perspective respectively.

Traffic management, together with relevant planning, design, construction, and operational practices, is a fundamental tool whereby the road environment can be made safer. It directly affects the physical road environment in which road users operate, and thereby influences the behaviour of road users. The practitioners on the other hand need to be cognisant of road users' behaviours when selecting proposals.

The primary cross-references to road environment safety as outlined in this Guide are the various Parts of the *Guide to Road Safety* and the *Guide to Road Design*. The *Guide to Road Safety* addresses some of the material in this Guide, but in more detail and in a broader safety management context. Similarly, in the *Guide to Road Design* safety aspects are covered in the context of the design approaches and practices presented.

This Guide summarises and draws together this safety-related guidance material in the context of the strategic application of traffic management practice to achieve safer operation within the road and traffic environment. The safe road environment is also considered and covered in Section 2.4 which outlines the Safe System approach to maximise safe mobility.

Appendix A provides an overview of where guidance and standards may be found in the guides and standards with respect to the basic elements of the road environment and the characteristics of a safe road environment.

1.4 Outline

Part 13 introduces road environment safety under the general Safe System philosophy, and emphasises the need for the road system to provide an environment which assists road users to behave effectively and safely.

It presents material with the primary focus on traffic management and traffic engineering practice, as follows:

- defines a safe road environment and the broad approaches for achieving it, within the Safe System concept (Section 2)
- outlines basic human factors related to users of the road and traffic environment, and how these can be influenced by road design and traffic management practice (Section 3)
- describes the basic components of road safety engineering and its application in terms of risk engineering concepts, primary strategies and safety management systems (Section 4)
- outlines the principles and practice of managing safety in the road environment, as related to features of the road infrastructure and the basic tools of traffic engineering and management (Section 5).

2. Safe Road Environment

2.1 Safe System Approach

Safe System principles have been acknowledged in successive national road safety strategies and action plans for over ten years as the guiding principles for road safety programs in Australia. The commitment is continued in the National Road Safety Strategy 2011–2020 (Australian Transport Council 2011). Safe System principles are also central to New Zealand's Strategy 2010–2020: the Safer Journeys Strategy (Ministry of Transport 2014).

The Safe System approach demands a holistic approach to the safety of the road system, with the aim of no person being killed or seriously injured on the road network. All elements of the road system, including safe roads, safe vehicles, safe road use and safe speeds are incorporated in the approach with responsibility required from stakeholders, including the road agencies, governments and road users. Details are given in the National Road Safety Strategy 2011–2020 (Australian Transport Council 2011) and incorporated in the Guide to Road Safety Parts 1, 2, 3 and 7 (Austroads 2013a, 2013b, 2008a, 2006a).

The Safe System takes human errors and frailty into account, acknowledging that crashes will continue to occur but seeking to avoid death and serious injury as outcomes. Speed is a critical element in this approach. Speeds must be contained so that in the event of a crash the impact forces remain below human injury tolerance.

The goal of the Safe System is to provide safer travel and traffic movement for all road users by minimising the risk posed by the interacting elements of the road transport system. The Safe System approach is shown in Figure 2.1 and is based on the following four cornerstone areas of intervention (Australian Transport Council 2011):

- Safe roads – Roads and roadsides designed and maintained to reduce the risk of crashes occurring and to lessen the severity of injury if a crash does occur. Safe roads prevent unintended use through design and encourage safe behaviour by users.
- Safe speeds – Speed limits complementing the road environment to manage crash impact forces to within human tolerance, and all road users complying with the speed limits.
- Safe vehicles – Vehicles which not only lessen the likelihood of a crash and protect occupants, but also simplify the driving task and protect vulnerable users. Increasingly this will involve vehicles that communicate with roads and other vehicles, while automating protective systems when crash risk is elevated.
- Safe people – Encourage safe, consistent and compliant behaviour through well-informed and educated road users. Licensing, education, road rules, enforcement and sanctions are all part of the Safe System.

Providing a safer road environment involves application of road design and traffic management principles with a clear safety focus. Practitioners responsible for the road network should ensure that the road is designed and managed from a safety perspective, and that its operation is adequately monitored and measured.

Safe System treatments used to improve the safety of the road environment, may be classified as either primary or supporting treatment. Primary treatments focus on reducing the severity of crashes while supporting techniques focus on reducing the number of crashes.

It is expected that Safe System principles and their application in Australia and New Zealand may continue to evolve in the future as the knowledge base expands through further research and experience of road agencies.

Figure 2.1: Safe System in the National Road Safety Strategy

Source: Department of Infrastructure and Regional Development (2016).

2.2 Elements, Concepts and Definitions

2.2.1 Road Environment Elements

The road environment can be defined as comprising the following elements:

- the structure on which the road users operate – the surface on which motor vehicles, motorcycles and bicycles are driven or ridden, on which pedestrians may walk, and on which animals may be ridden or driven
- the traffic activity on the road – the extent and mix of vehicle types and road users: cars, heavy vehicles, buses, trams, motorcycles, cyclists and pedestrians
- the items to the side and sometimes in the centre of the road – these can be naturally occurring or man-made, and include poles, trees, embankments, culvert headwalls and footpaths
- the devices placed on and adjacent to the road for managing the traffic it carries – for example, traffic signals, signs and markings and safety barriers
- the land use adjacent to the road, which generates traffic movements – for example, shopping centres, schools, residences, parks, mines and ports.

The elements of a road environment are provided by:

- road agencies – providing the road network upon which road users travel and the traffic systems which manage road user activities within the network; this includes design, construction and operational management
- the natural environment – providing the terrain, natural features and weather conditions
- other bodies – providing infrastructure features, some of which can influence road user behaviour; for example, adjoining development which can affect how road users interact with the road; building facades, advertising billboards, utility service structures and commercial lighting (these are extraneous to the road transport system and may cause visual clutter, roadside hazards and distraction).

The last two points should be recognised and addressed by road agencies as they can affect the performance of the traffic management network elements they provide.

2.2.2 Safety Concepts and Definitions

A safe road environment should serve the safety needs of all road users. It is one which:

- provides as low a level of risk as practicable, within budgetary constraints, for all road users
- incorporates appropriate design principles and geometric design standards, good delineation under all conditions, adequate surface skid resistance and a roadside free of unforgiving hazards
- includes sufficient traffic management devices to guide and control the passage and speed of road users efficiently and safely.

The road environment comprises physical elements that road users perceive, and to which they respond. A safe road environment is one which elicits the correct responses from road users. That is, in an ideal safe road environment, road users respond correctly, stay on track, avoid collisions, and reach their destinations. In a realistic situation, road users make mistakes. A safe road environment should aim to generate the correct response from road users and to minimise the severity of their consequences if a road user makes a mistake.

A safe road environment cannot be defined purely in terms of road user behaviour. It can be defined in terms of its fundamental elements, and in terms of how those elements influence road user behaviour.

Guidelines for providing a safe road environment must consider the fact that drivers need to perceive and process information, make decisions and react within finite time intervals. Comfortable and safe driving occurs when motorists are operating well below a stressful processing and decision-making rate and above a minimum level of arousal. These aspects of a road user's abilities and actions are critical considerations in developing and maintaining a safe road environment.

A safe road environment can be defined as one which provides, for all road users, the features listed in Table 2.1.

These simple principles form the basis of road environment safety in terms of the physical environment in which crashes might occur, and the information provided to the road user. The design of road and traffic engineering elements should, within practical limitations, accommodate the physical, perceptual, and cognitive abilities of all road users as well as the physical performance limitations of all road vehicles, and the injury tolerance of road users. The principles for achieving a safe road environment are applicable to all stages of road network development – planning, design, construction, maintenance, and operations.

Table 2.1: Defining a safe road environment

A safe road environment should:	So that:
Warn	Road users are warned of any approaching substandard, unusual or complex features in the road environment that pose an unexpected elevated risk
Inform	Road users are informed of the way ahead, and of the type of unusual conditions likely to be encountered
Guide	Road users are guided along sections of a route and through unusual sections of a route
Control	Road users are controlled at conflict points or areas of conflict, and their speeds are managed
Forgive	Errant road user inappropriate behaviour or mistakes are forgiven, with the severity of consequences being minimised
Contain no surprises	Reliable and consistent road user responses and performance may be expected
Provide a controlled release of information	Road user information overload is avoided
Repeat information where necessary	Crucial information is unlikely to be missed, overlooked or forgotten by road users
Provide information in a consistent manner	Similar situations are treated in a similar manner, as road users would expect, based on their expectations built up from previous experiences
Provide adequate surface friction	Reasonable and predictable surface friction requirements are met, and recovery from emergencies is facilitated
Provide opportunities for rest and recuperation	Road users can rest and avoid the effects of fatigue, particularly on longer trips on rural highways

Source: Adapted from Roads and Traffic Authority (2006).

The *Guide to Road Safety Part 8* (Austroads 2015k) provides general guidance on the application of the safe road environment principles to intersections, road sections and various devices installed in the road environment. Further material is presented in Section 5 of this Guide.

2.3 Achieving a Safer Road Environment

A safer road environment can be achieved through improvements in the design, construction and development of the road network, and in traffic management, such that driver behavioural needs are met and their capabilities, including injury tolerance, are not exceeded. It is not possible, within practical limitations, to achieve an ultimate level of safety through design and management of the road environment, so other initiatives aimed at managing speeds must also be pursued.

It is necessary to ensure that the road design and its associated traffic management facilities are fundamentally safe before the road project is built, and by correcting problem locations in an existing road network as they are identified.

Practitioners should ensure a safer road environment from both the macro perspective (the safety performance of the road network – or of specific road types within the network) and the micro perspective (the inherent safety characteristics of road sections).

These approaches involve adopting fundamental concepts such as safety auditing, Safe System auditing, remedial countermeasure treatments and network risk assessment. An analytical and structured approach is required, involving application of the discipline known as road safety engineering.

Austroads (2015d) provides various tips to help deliver a Safe System during road planning phases. These are outlined in Table 2.2.

Table 2.2: Tips for achieving a safe road environment

Interaction with land use
• Provide for mixed-use communities that will reduce travel distances to help to minimise safety risks when people travel to access services, facilities and social networks. • Consider different mixes of road users and their specific needs in different types of developments (e.g. strip shopping centres, residential neighbourhoods). • Provide connected, attractive and pleasant public spaces to encourage people to walk and cycle for short trips away from roads. • Promote subdivisions and local development patterns that contribute to a safe low-speed interaction between all road users. This promotes liveable neighbourhoods, business districts, and reduces the road footprint. • Limit the number of access points onto roads with speeds higher than 60 km/h. • Require road safety audits for all scales of land development proposals. Ensure that the audits consider Safe System principles and consider the interaction with the broader road network. • Develop planning scheme objectives and acceptable outcomes aligned with the Safe System principles to promote safe road environments for pedestrians, cyclists, public transport, and commercial and private vehicles.
Different road users
• Where possible, design spaces such that motor vehicular traffic is separated from pedestrian and bicycle traffic, and maximise this separation in high-speed areas. In addition, separation of pedestrian from bicycle traffic is desirable where possible, particularly in areas of high bicycle traffic. This minimises exposure of vulnerable road users to road safety risks. • Consider pedestrian and cyclist desire lines as well as visibility and locate crossings where road safety risks are minimised. • Where road use is mixed, design roads to encourage low speeds. For example, traffic speeds below 40 km/h are highly desirable in areas of high pedestrian and cycling activity. Road design and landscaping features can be used to encourage lower speeds. • Incorporate convenient public transport options to reach new developments (e.g. bus stops and train stations) given public transport is safer than travelling by car, bicycle, or motorcycle.
Roads and roadsides
• Establish and communicate a clear hierarchy within functional transport routes (e.g. link roads, collector roads and local access roads). Self-explaining roads help users understand different kinds of road environments, what speeds are appropriate for different kinds of roads, and which transport modes have priority within each route. This clarity promotes safer behaviour and fosters more liveable communities. For example: • narrow local access roads with off-street parking - wide clear verges and foot/cycle paths on medium- and high-speed roads - appropriate intersection and road access controls. • Design roads so that they fit with the abilities and expectations of the users that the road is primarily designated to address. This means designing the road in accordance with the Movement and Place function (as outlined in the *Guide to Traffic Management Part 4: Network Management* (Austroads 2016b)) of the road. Where the road is designated as more of a Place function the road should be designed to safely accommodate the most vulnerable road user (e.g. children, seniors, people with disabilities and cyclists) in a more shared environment. Where the road is designated as more of a Movement function then it should be designed to separate the vulnerable users as much as reasonably possible from the motorised traffic and utilise controls such as signals or grade separation to reduce the reliance on human cognitive limitations. • Design roads and roadside spaces to be self-explaining to their users. This means there should be no ambiguity or surprises for any users. • Advocate for a high level of safety features and work with designers and engineers to ensure speed management and speed limit decisions reflect the function and use of spaces. For example, lower speeds in built-up environments may improve safety of, and encourage, active travel modes while separation of conflicting flows and movements can help improve safety on high-speed roads such as link roads or arterials. Appropriate speed management limits the chance and severity of crashes. • Limit intersection through-speed to 50 km/h, for example through use of roundabouts to reduce the number of conflict points and the severity of collisions, taking due cognisance of vulnerable road users such as pedestrians and cyclists as well as other vehicle type needs (e.g. multi-combinational vehicles). • Provide for grade separated interchanges on higher order, high-speed roads. • Avoid visual and roadside clutter to improve visual amenity and minimise roadside hazards such as power poles, trees and street furniture that can kill and maim errant drivers and riders. For example, encourage the provision of underground services wherever possible.

Roads and roadsides (continued)
• Choose appropriate tree species by considering the mature height in relation to sightlines and trunks that are flexible on impact (no greater than 100 mm at full maturity), especially in higher-speed environments. • Protect vehicle occupants in the event of collisions with roadside trees and poles with barriers on medium- and high-speed roads, especially those with diameters ≥ 100 mm. • Plan for emergency service access, safe stopping and pull-over areas where applicable to minimise vehicle conflict points
Planning
• Understand and plan for new safety technologies and road-vehicle communication systems. • Plan and promote future public transport developments to encourage modal shift. • Set aside road space for future transport needs to accommodate the safety requirements for multiple modes and increasing traffic demands.

Source: Austroads (2015d).

2.4 Safe Mobility

To comply with the Safe System and to achieve a safe road environment, road agencies need to move towards maximising safe mobility.

While road safety has always been a focus for road agencies, safety has in the past been typically addressed through reactively addressing road network locations with a crash history. As outlined in Austroads (2016a), road safety practitioners are moving towards the Safe System approach which incorporates a more proactive approach to road safety based on the assessed potential crash risk of the road. Key features of the Safe System approach and how it addresses various issues associated with crashes are outlined in Table 2.3.

Table 2.3: Key features of the Safe System approach and how it addresses various issues associated with crashes

Issue	Safe System approach
Understanding of critical speeds at which fatal and serious injury (FSI) crashes occur for different crash types	Biomechanical tolerances are core to the vision of eliminating FSI crashes.
Road user error	A forgiving road and roadside is core to the Safe System. FSI crashes should not occur because of driver error. Vehicle and infrastructure improvements should be used to reduce impact forces (should a crash occur) to below human tolerances, and therefore reduce crash severity.
Shared responsibility	Road managers/designers share the responsibility for safe travel outcomes by accommodating road user error.
Design requirements	It is paramount that new infrastructure assists in eliminating death and serious injury. This also includes speed management and separation of road users travelling in different directions or of different mass.
Crash severities addressed	FSI crashes should be the main aim and starting point in site identification. Minor and non-injury crashes may be useful to provide additional information, but are not the core focus.

Source: Austroads (2016a).

While the Safe System approach has been adopted in Australia and New Zealand for over ten years, it is evident that there is a lack of clarity on how to integrate the approach into the daily activities of engineering practitioners. Austroads has commissioned a project titled Translating Safe System Research and Knowledge into Practice: A Guide for Practitioners to provide guidance on this (Reference to be added once published).

Harm minimisation is an integral component of Safe Systems. That is, road design and traffic management needs to also consider how to reduce the severity of crashes when they occur. In engineering terms, harm minimisation means the consideration of impact energy: as manipulating speed, mass and crash angles can reduce crash injury severity. Speed is at the heart of a Safe System and aspirational design speeds include: 30 km/h (car vs pedestrian/cyclist), 50 km/h (car vs car side impact at 90 degrees) and 70 km/h (car vs car head-on). Self-explaining roads and the principles of Movement and Place in urban design provide effective ways to support differing speed environments and road functions. Some common ways to minimise harm for different road environments include:

- altering the impact angle away from 90° and lowering the impact speed at intersections
- protecting corridors with flexible barriers to prevent high speed lane departures on rural roads
- lowering the speed or separating vulnerable road users from other motorised vehicular traffic.

Tools and frameworks are now emerging that allow the Safe System to be quantified. Some of these frameworks are identified and discussed in Section 4.4 and Section 4.5.

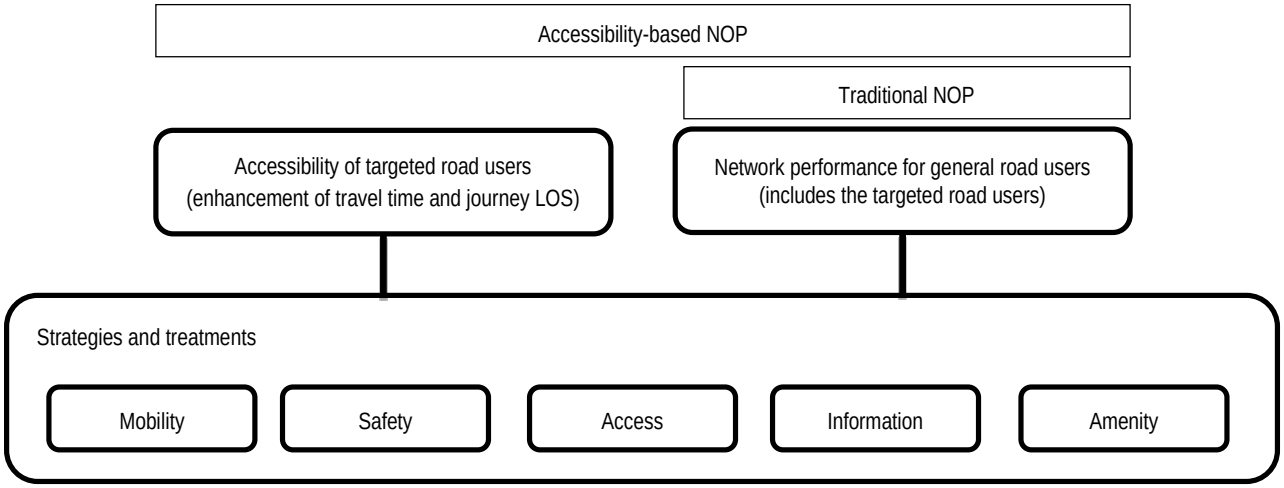
The shift towards the Safe System approach and delivery of safe mobility is a key component of network operation planning. As outlined in the *Guide to Traffic Management Part 4: Network Management* (Austroads 2016b), a network operation plan (NOP) which is the output of the network operation planning process, aims to guide the operation and development of road/transport networks towards managing competing priorities.

An NOP underpins higher level strategic plans and should be developed in full consultation with stakeholders and the community. One of the key planning principles in an NOP is to provide safer road travel for all road users and move towards the broader application of the Safe System.

The *Guide to Traffic Management Part 4: Network Management* (Austroads 2016b) provides a level of service (LOS) framework that allows users to assess the various LOS measures for five road user types (private motorists, transit users, pedestrians, cyclists and freight operators) and the five needs (mobility, safety, access, information and amenity). The LOS framework enables practitioners to measure LOS gaps because of implementing road strategies. This enables practitioners to implement an NOP as the LOS framework helps to understand the LOS for various road users and their needs. As safety is one need, safety LOS defines the various safety needs for various road users and provides a measure to assess how effectively the road environment meets these safety needs.

Accessibility-based NOP extends the traditional NOP by focusing on targeted road users and their journeys rather than on just links. The accessibility-based network operation planning LOS framework, incorporates safety as a user need and is based on Safe System principles (as outlined in Austroads (2015d)). By expanding to include various road users and their needs, the framework assists practitioners in understanding the appropriate safety LOS for the various users relative to the intended function and role of the road. The role may change by location, day and time along a road. For example, while a road may be classified as an arterial or highway, it may go through an activity centre and therefore its function may change. This may result in local area traffic management facilities being put in place to improve safety, mobility, amenity and access to the activity centre for vulnerable road users. The concept of accessibility-based NOP is shown in Figure 2.2.

Figure 2.2: Network Operation Plan with consideration of accessibility needs of targeted road users



Source: Austroads (2016b).

From a hierarchical sense, the *Guide to Traffic Management Part 4: Network Management* (Austroads 2016b) is above the *Guide to Traffic Management Part 5: Road Management* (Austroads 2017e). Further still an NOP is above any individual road management plan and guides how a road should be managed to meet the objectives of the NOP.

Practitioners should refer to an NOP to implement safe mobility. Doing so enables the clarification of the function and role of different segments of the road at different segments of time. Additionally, it enables practitioners to understand the safety LOS for the various users of that segment of road, for that time. An example of safe mobility as opposed to a more traditional approach, balancing efficiency with safety, is the shift towards the use of fully controlled right-turns as opposed to filter right-turns, where safety may pose a risk. While the filtered right-turn may offer some efficiency gains, by allowing right-turns to filter through the opposing through movement, in some cases it may pose a safety risk. Therefore, fully controlled right-turns are preferred from a safe mobility perspective. The *Guide to Traffic Management Part 5* (Austroads 2017e) and the *Guide to Traffic Management Part 6* (Austroads 2017f) provide guidance to practitioners on the management of roads from the mid-block and intersection perspective respectively. To comply with the Safe System, practitioners should focus on implementing strategies that maximise safe mobility.

Austroads (2015e) outlines that speed management is a core component of a Safe System and remains the best opportunity for rapidly reducing road trauma. The critical role of speed in the Safe System was recognised by the National Road Safety Strategy with safe speeds being a key pillar of the Safe System. Physical devices may be used to achieve a speed environment that is compatible with the road activity and often requires alteration of the road geometry to reduce the speed of the environment. Practitioners should consider speed management as a potentially effective approach to managing safety risk. Speed management is discussed throughout the *Guide to Traffic Management*, the *Guide to Traffic Management Part 5* (Austroads 2017e), the *Guide to Traffic Management Part 7* (Austroads 2015b) and the *Guide to Traffic Management Part 8* (Austroads 2016c).

3. Human Factors and the Need to Design and Manage Roads to Achieve a Safe System

The contemporary approach to managing the occurrence and consequences of crashes in the road system is based on the Safe System concept (Section 2.1). A basic element in this approach is the management of the physical environment, especially the road environment, to minimise harm to those involved in crashes. Underpinning this is a need to understand the basic interactions among the traditional major components of the road traffic system – the road user, the vehicle, and the road environment. These interact as contributing factors to road crashes.

Traffic crashes arise from complex chains of events involving the interaction of several factors over space and time. Crashes are multifactor events which reflect a malfunctioning of the road traffic system – a breakdown in the ideal operation of a vehicle and its human operator in the road traffic environment.

Traffic management initiatives are devised and implemented in the road environment with the fundamental purpose of influencing road user behaviour. It is therefore important for traffic management practitioners to understand the basic characteristics of human behaviour in the context of road use.

3.1 Human Factors

The term human factors are widely used to describe the aspects of human behaviour which relate to the interaction between humans and their environment.

A useful general definition of human factors is:

> *The discovery and application of information about human behaviour, abilities, limitations, needs and other characteristics to the design of tools, machines, systems, tasks, jobs and environments for productive, safe, comfortable, and effective human use (Sanders & McCormick 1993).*

The term ergonomics is often used interchangeably with human factors. A useful simple definition of ergonomics is:

> *The study of design of the working environment so that optimum use is made of human capabilities without exceeding human limitations (Grandjean 1988).*

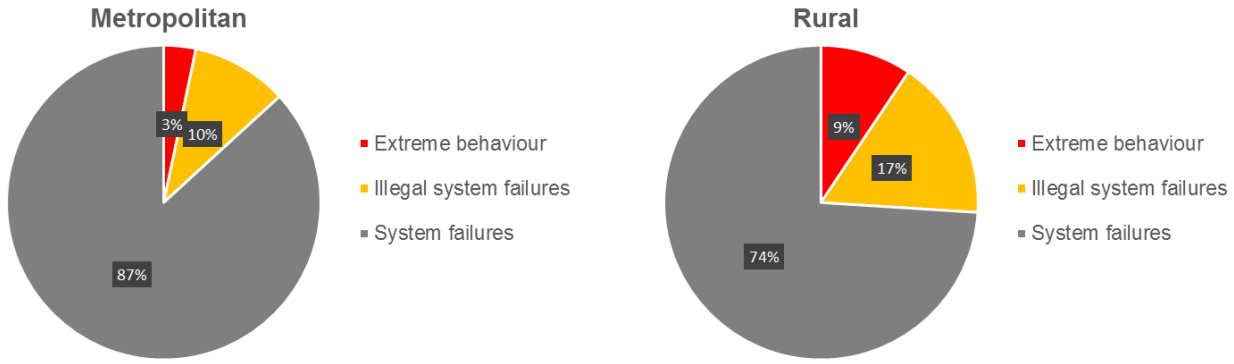
3.2 Human Factors and their Role in Road Safety

As outlined in Austroads (2016a), the Safe System recognises that it is the unforgiving road and the vehicle system that plays in combination with human factors that cause casualty crashes. When the road and vehicle environment allow it, human factors can result in crashes with a human being killed or seriously injured. The Safe System and how it views the contribution of the human driver in crashes, relative to other system failures are indicated in Figure 3.1. Figure 3.1 shows that the cause of casualty crashes can be categorised into three areas:

1. extreme behaviour
2. illegal behaviour
3. system failure – common errors and mistakes.

While there may be differences in the split for rural and metropolitan, the common element is that system failure makes a large contribution to crashes.

Figure 3.1: Safe System view of human factors in road safety



Source: Based on Wundersitz, Baldock and Raftery (2015).

The road system needs to make allowance for human factors by providing a forgiving road environment which reduces casualty outcomes in the event of a crash.

It is important to remember that the four pillars in the Safe System (safe roads, safe vehicles, safe speeds and safe road users) are all important. Attention must be given to making roads, vehicles and speeds more forgiving, as well as continuing to work towards achieving greater levels of road user compliance with the road rules.

When a road user makes an error of judgement (either consciously or sub-consciously), the system should compensate and provide adequate protection to all road users. As a result, various aspects relating to human factors need to be considered in the Safe System, to compensate for these human factors which may contribute to an error of judgement and therefore make the road more forgiving. These include:

- stimuli and the human factors contributing to crashes
- traffic management and road design in the context of the driver
- the driving task
- driver characteristics.

These human factors are discussed below, with further detail contained in the Appendices of this Guide.

3.2.1 Stimuli and the Human Factors Contributing to Crashes

Humans respond to stimuli to make decisions, but sometimes the decision made by a human can be wrong for a scenario. In the road environment, this can lead to a crash and therefore the road system must be designed to take this into account. Further information on the human factors contributing to crashes and the considerations for design are discussed in Appendix D.

3.2.2 Traffic Management and Road Design in the Context of the Driver

Road engineering and traffic management practices have been refined over the years through the incorporation of behavioural research into the standards and guidelines. The standards must be met, while the guidelines provide a base level for good practice. Each situation may have unique characteristics, which means that best practice may not accommodate the typical road user response and therefore the appropriate treatment used needs to be determined on a case-by-case basis. This means that the layout of the road and the traffic management used needs to be designed to assist the user in their task.

Common practice includes:

- not adopting the minimum standard for many parameters at one location as it will potentially make that location unsafe (e.g. not having the minimum sight distance requirement plus minimum horizontal curvature requirements)
- installing signage and marking along a roadway that is suitable for a road user approaching a road environment for the first time and not knowing what is ahead.

Appendix E discusses traffic management and road design in the context of the driver in further detail.

3.2.3 The Driving Task

The driving task can be subdivided into the following:

- Strategy: refers to factors such as overall route planning and scheduling.
- Navigation: relates to route finding.
- Guidance: relates to route following.
- Manoeuvring and control: relates to the performance of individual movements in the traffic stream.

The driving task requires drivers to process information (both static and dynamic information). This requires drivers to sense inputs (mostly visual), interpret and process them, make decisions, execute actions, and observe their effects through the reception and processing of new information. The driver's task:

- involves mental activity in processing the information received from the environment
- relies on memory and experience to guide decisions about the necessary actions
- involves physical activity in giving effect to those actions.

The driving task is discussed further in Appendix F.

3.2.4 Driver Characteristics

Aspects that can influence driver behaviour include:

- psychological traits (intelligence, learning, skills, motivation, desires and attitudes)
- sensory abilities (vision and hearing)
- physical abilities (perception and reaction times – perception and motor response)
- medical factors (influence of drugs, disease, impairment and emotional stress).

These aspects can affect behaviour, which can influence the driver and the tasks undertaken. Further still, the ability of the driver to receive and process information can be influenced by various human-related factors which need to be considered in a Safe System. The various factors include:

- Visual characteristics: This includes the extent of the visual field, peripheral vision, eye and head movements, responses to low illumination and glare, and colour vision defects, which can all play an important part in influencing the receipt of information.
- Perception and reaction times: The perception and reaction time is the time consumed by a road user between the stimulus and decision/action. Safe System needs to make allowance for the perception and reaction times, with road safety engineering aiming to avoid extended perception and reaction times by creating situations where stimuli may be promptly detected and consistently interpreted.
- Short term memory: This is the information held in temporary storage while processing earlier inputs. Short term memory has implications for the sequencing of information. This results in information being displayed in an orderly and timely fashion, and repeating information where necessary.

- Expectancies: In a Safe System, the presentation of stimuli, such as signs and markings, should be undertaken in a standard and expected way to help reduce reaction times and extend detection distances.
- Information processing capacity: Safe Systems need to consider the limits to human information processing capacity. At high levels of demand, performance (correct responses) falls away and eventually an overload situation is reached, while if demand is too low, the alertness of the driver may be low, causing delay in perception and reaction time due to lack of vigilance.
- Medical factors: This includes physical or mental disabilities, emotional state, or the effects of alcohol, drugs, disease or fatigue. These can all influence the information processing abilities of drivers.
- Age related factors: Age can play a role in the capabilities and limitations of drivers. Age can be problematic at both ends of the spectrum, as drivers age there is a decline in the sensory, cognitive and motor skills which can affect the ability to drive. At the lower end, lower age can coincide with inexperience which can affect the driver's ability to perceive hazards

The driver characteristics, behaviours, capabilities and limitations are discussed in further detail in Appendix G.

3.3 Managing the System

In managing the road in accordance with Safe System principles, practitioners should consider the human factors outlined above and in Appendix D to Appendix G. The information processing capacity of a human operator suggests that a crash may reflect an overload situation for the driver – an inability to process effectively the information presented by the road/traffic environment, resulting in an inadequate response to the demands imposed by the system. This less than ideal behaviour may be managed by:

- modifying the behaviour by training and educating drivers
- controlling the behaviour by imposing restrictions and enforcing them
- removing misleading/conflicting or ambiguous information
- accommodating the behaviour by designing the environment to suit driver capabilities and expectancies
- accommodating the behaviour by dynamically changing the environment to suit driver capabilities, for example, using ramp metering to regulate entering traffic.

The behaviour management techniques are not exclusive. For example, the behaviour could be controlled to a certain limit (e.g. amendments to road rules) and the environment changed to accommodate this new level of behaviours. As a road is a system, management of the road system in accordance with Safe Systems principles involves managing inter-relating components.

Road and traffic engineering practitioners' efforts are primarily focussed on delivering the last two approaches in seeking to achieve a Safe System. This is the ergonomic approach – designing the task to fit the human operator. There are obvious implications for the practitioner to ensure that the road environment does not place demands on the driver that are too high or that are outside normal expectancies.

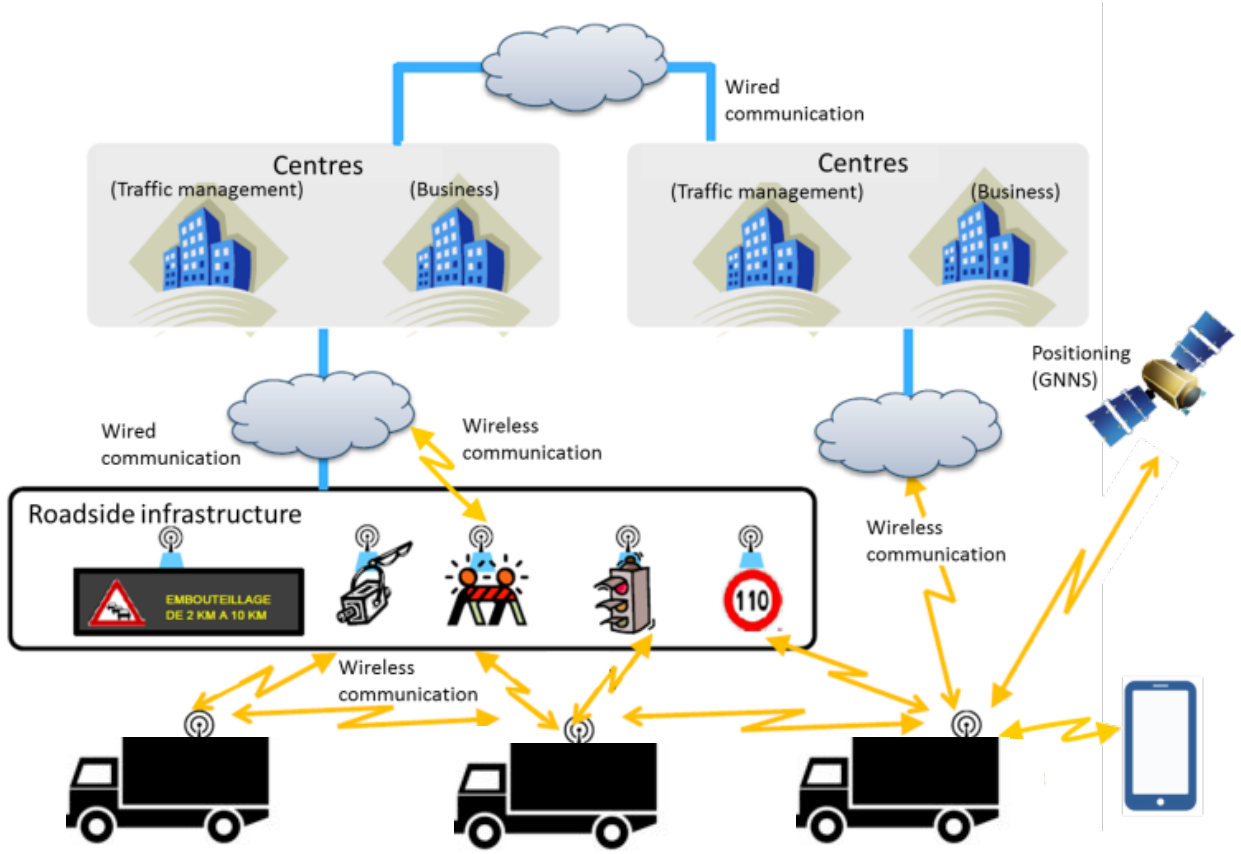
In practice, all approaches are used in varying combinations, depending on the issue being addressed.

3.4 Technology and its Impact on Human Factors in the Safe System – Safe Vehicles

Various in-vehicle technologies are emerging such as cooperative intelligent transport systems (C-ITS) and automated driving technologies.

C-ITS is an emerging intelligent transport system technology that will facilitate wireless communications and the sharing of information between vehicles (V2V), roadside infrastructure (V2I) and centres (V2C). The term V2X is used to describe the communication between vehicles and any entity. C-ITS will allow vehicle and transport applications to work together cooperatively in a standardised manner using a variety of communication media (the most appropriate communication medium available at the time for the specific application). A conceptual view of C-ITS is shown in Figure 3.2. Reports such as Austroads (2012a) and Austroads (2015g) provide further detail on C-ITS.

Figure 3.2: Cooperative intelligent transport systems



Source: Austroads (2015g).

Figure 3.2 illustrates the functionality of using C-ITS to obtain various information. This information may be used to deliver a range of safety outcomes. For example, information pertaining to the speed limit, signal phase and timing, roadworks and geometric intersection data may be communicated directly from the roadside infrastructure with the driver or vehicle responding to the information, depending on the application, to achieve safety outcomes. Alternatively, if the systems are in place to store this information centrally, this information may be communicated from centres.

Automated driving technologies in vehicles are also emerging, where the technology will take over some of, or all, the driving task depending on the level. A summary of the various automated driving levels as specified by the SAE J3016:2016 standard is outlined in Table 3.1.

Table 3.1: Automated driving levels

Level	Feature	Status
0	No driving automation All driving tasks are undertaken manually.	Currently available with many vehicles being sold meeting SAE level 0. Example technologies include: • lane change assist • park distance control • lane departure warning • front collision warning.
1	Driver assistance Many of the driving tasks are manual but some tasks are assisted (e.g. steering, braking)	Currently available with some vehicles being sold meeting SAE level 1. Example technologies include: • adaptive cruise control • park assist (driver controls the brake and accelerator) • adaptive cruise control including stop and go • lane keeping assist.
2	Partial driving automation Some tasks are automated but hands must remain on the steering wheel	Emerging technology with a few vehicles being sold meeting SAE level 2. Example technologies include: • traffic jam assist • park assistance (driver can be outside the vehicle).
3	Conditional driving automation All aspects of driving are automated but the human driver must be ready to take back control when prompted	Technologies to potentially emerge in the near future (e.g. to 2020) with example technologies including: • traffic jam chauffeur • highway chauffeur.
4	High driving automation All aspects of driving are automated with the driver being able to take back control if needed	Technologies to potentially emerge in the medium future (e.g. to 2025) with example technologies including: • parking garage pilot • highway urban pilot • urban and suburban pilot.
5	Full driving automation No human interaction required	Technologies to potentially emerge in the distant future (e.g. to 2030) with example technologies including: • fully automated pilot vehicle.

Source: Based on ERTRAC (2015).

One of the interests of road agencies in these technologies, which may be implemented in combination, is the delivery of safe vehicles through the vehicle undertaking some or all the driving tasks and therefore not subjecting that task to human factors. However, to achieve this the vehicle may require certain information from the infrastructure and be interoperable with it. For automated driving, which relies on sensors to read the road and the road environment, automated driving will require that the road and the road-related infrastructure (signage and line marking etc.) be able to be read by the vehicles. This is discussed in the *Guide to Traffic Management Part 10: Traffic Control and Communication Devices* (Austroads 2016e).

4. Road Safety Engineering

Traditionally, road safety programs have had an emphasis on dealing with factors such as speeding, drink-driving, vehicle occupant protection and vehicle crashworthiness. In the background has been the continual development of the physical road environment in which crashes take place. Numerous standards and guidelines have been developed for this and have taken safety into account.

Road engineers and managers have a prime responsibility for addressing the safety factors related directly to the road environment. This is achieved through engineering design and management activities that have a clear safety focus – road safety engineering. They should be applied at all stages of road/transport development – for example, the planning of new developments, the design of new roads, safety improvements for existing roads, remedial treatments of hazardous locations, routine maintenance programs and operation of the roads. Good road safety engineering in the design stage is critical to creating a Safe System.

4.1 Definitions

Road safety engineering can be described as the process by which a safer road environment is provided. It can be considered as the application of traffic and road engineering practices with the aim of preventing crashes and managing risk so that the chances of death and serious injuries are as low as practically possible. It also gives effect to the philosophy that one should aim to provide a road network or system which does not unduly injure the users of the system.

Road safety engineering is an augmentation of basic road and traffic engineering expertise. The various tools of trade in road safety engineering may be categorised as follows:

- data – for traffic mix and volumes, travel speeds, road features, asset condition, traffic facilities, crashes and costs
- guidance – various widely accepted standards, guidelines and codes of practice
- procedures and processes – highway inspections, crash investigations, remedial treatments, road safety audits of designs and existing roads, road network reviews and related surveys of specific issues
- analytical techniques – risk assessment, crash rates analysis, economic analysis, countermeasure evaluation studies, crash prediction modelling and target setting
- knowledge – sound knowledge in traffic engineering and road design practice, road safety engineering research reviews, knowledge and judgement.

Road safety engineering requires that the road network, and any additions or modifications, be examined and managed in a systematic manner – using the above tools – to ensure that the elements of a safe road environment (Section 3) are provided.

4.2 Objectives

From the traffic management perspective, an overall aim is to facilitate traffic movements on the roads with safety and efficiency, considering the needs of a range of road users. A broad objective is to provide high levels of safety, accessibility, amenity and environmental quality in the area under study. Specific safety objectives include:

- enhanced safety of a route or area (arising from crash analysis or from direct community concerns)
- improved safety, mobility and accessibility for children, pedestrians and cyclists.

Road safety engineering applies engineering principles to improve the safety of the road environment and reduce the total cost of road crashes to the community in a cost-effective manner. This involves managing – and reducing – the risk of serious injury presented to road users by the road and traffic environment.

A fundamental objective in road safety engineering is to ensure the road network presents a consistent environment to road users to elicit safe responses. A consistent road environment, in terms of appearance and control features (road design and traffic management), assists road users in their decision-making and behavioural responses.

4.3 Methods and Approaches

4.3.1 Analytical Basis

The Safe System approach recognises that humans are fallible and will continue to make mistakes on the roads. Additionally, humans can only withstand limited amounts of kinetic energy exchange when a crash occurs before death or serious injuries result. A system is required to address the problems that encompass road users, vehicles, roads, speed and post-crash care solutions.

Appropriate infrastructure is required to consider road user vulnerabilities and fallibilities to avoid death or serious injury should a crash occur. This system approach implies a shared responsibility for addressing fatal and serious crash outcomes. Road managers have a significant role in addressing these outcomes. It is not acceptable to blame the road user for a crash outcome when there are infrastructure solutions that may be applied to help reduce this risk.

Haddon (1980) identified a systematic framework for road safety based on an epidemiological model. This comprises infrastructure, vehicles and users in pre-crash, in-crash and post-crash stages. An understanding of these phases permits possible countermeasures to be considered. Road safety engineering treatments can be applied to reduce the probability of a crash occurring in the first place (pre-crash) and secondly to reduce crash severity should it occur (crash). Thirdly, although to a lesser extent, road safety engineering can ensure that rescue services can reach a crash site promptly (post-crash). An example of a Haddon Matrix is shown in Table 4.1.

Table 4.1: Haddon matrix showing examples of countermeasures

Element	Phases		
	Before a crash	During a crash	After a crash
Human	Training, education, behaviour (e.g. not drinking), attitudes, enforcement, conspicuous clothing on pedestrians and cyclists, exposure control.	Wearing in-vehicle restraints.	Prompt emergency medical service response, better trauma care.
Vehicle	Primary safety (e.g. good brakes, roadworthiness, visibility).	Secondary safety (e.g. occupant protection, crashworthiness).	Devices to attract attention (e.g. mobile phone, horn).
Road	Road design (e.g. delineation, good road geometry, good surface condition, visibility).	Roadside safety (e.g. clear zones, frangible poles, vegetation selection, adequate safety barriers).	Median breaks and shoulders provided on freeways to facilitate access for emergency vehicle, ITS congestion and incident management.

Source: Austroads (2013b), adapted from Haddon (1980).

Although it has been long understood that a priority is to address more severe crash outcomes, the Safe System brings this concept into further focus. The key objective of the Safe System approach is to address fatal and serious crash casualty outcomes. In some cases, this has meant a re-shaping of how crash analysis is conducted, and how treatments are selected (including the types of treatments) to address risk.

Further discussion on the Safe System approach in crash analysis and treatments is provided in the *Guide to Road Safety Parts 1, 2, 7, and 8* (Austroads 2013a, 2013b, 2006a, 2015k).

4.3.2 Documented Guidance

Many documents provide information and guidance relating to road safety engineering. Practitioners have a responsibility to operate within these requirements, and should refer to such documents in seeking to achieve a consistent road environment. These documents include:

- legislation – mandatory legal requirements for behaviour and equipment
- standards – formal technical specifications based on agreed baseline practice
- guidelines – technical guidance for practitioners based on consolidated experience and acknowledged best practice
- codes of practice – agreed industry practice, often on specific issues or operations
- manuals – typically corporate statements of policy and procedures for implementing programs in accordance with standards, guidelines and best practice.

Much relevant information and guidance aimed at achieving a safer road environment is incorporated in various guidelines and standards. These are based on many years of research into the effectiveness of safety-related road design features and traffic management initiatives, and on the consolidation of acknowledged best practice. The aims of standards and guidelines are to provide:

- better outcomes in terms of efficiency, safety and investment
- consistency in tools and their practical application, and ultimately in the road environment
- a mechanism for updating best practice based on research results, technological developments and innovation.

A road agency should clearly specify its legislative and technical operating environment, identify relevant documents applicable for managing the road network in its jurisdiction, and introduce policies and procedures to ensure they are consistently adopted within the organisation.

Departure from consistent use of specified standards and guidelines can lead to an inconsistent road and traffic environment, inconsistent road user behaviour and increased crash risk. Following guidelines alone does not always guarantee an acceptably safe road environment. Where design guidelines allow adoption of minimal criteria, practitioners need to be aware of the consequences of always adopting minimal standards or adopting several minimal criteria for road features near each other. The resulting environment can be deficient with regard to safety considerations. There is a need to ensure that the road and traffic environment is assessed specifically in terms of its potential and actual safety performance.

4.3.3 Strategic Approaches

Road safety engineering is most appropriately not conducted in a vacuum. It should be the underpinning of a broader safety management system in which specific strategies for enhancement of the road environment are identified.

Road safety strategies may involve initiatives aimed at exposure control, crash prevention, managing and maintaining safety elements of the road infrastructure such as clear-zones, behaviour modification, injury control or post-injury management (Ogden 1996). Road safety engineering is aimed primarily at crash prevention but also behaviour modification and injury control.

Central to the successful provision of a safer road environment is the risk assessment approach, and applying the concepts of risk engineering and management. These are outlined in Section 4.4, and the primary strategies guiding the application of road safety engineering practice are outlined in Section 4.5.

4.4 Risk Engineering Concepts and the Safe System Assessment Framework

Risk management can be considered as a broad strategy. Risk engineering is a detailed analysis of the occurrence and consequence of risks, and their preventative treatment.

Risk engineering is the development of engineering models that demonstrate the processes leading to unwanted outcomes, in this case, road crashes. Risk engineering is concerned with describing how risk occurs and how interventions are best undertaken. Risk engineering models show the occurrences or mechanisms leading to an event and the outcomes and damage occurring as a result. These models show how risk manifests in an area of activity; the models alone do not lead to risk management.

A safe road environment can be considered in risk engineering terms. A road environment is populated with moving objects, including vehicles of many different types (cars, freight, on-road public transport, bicycles) with human occupants, users, and pedestrians. When in motion, all objects possess kinetic energy. As with all energy sources, kinetic energy has the potential to do damage.

In a risk engineering context, the event is defined not as the crash (which is an outcome), but as the point when control is lost or when poor decisions are made. This definition allows the inclusion of situations where a driver initially loses control or makes an error and then regains control (a null outcome) without causing damage. By using this definition of the event, the importance of a forgiving road environment is more obvious. Allowance can be provided for road user error and the opportunity for recovery from an initial loss of control. Similarly, in the case of a two-vehicle right-angle crash at an intersection for example, the event could be defined as the point at which control is effectively lost. The definition allows for the possibility that control could be regained, by swerving or braking, leading to a null outcome.

Austroads (2016a) uses the concept of risk assessment in its framework. The completion of the Safe System Assessment Framework ensures that Safe System elements are considered and measures how well a given project (e.g. an intersection, road length, area and treatment type etc.) aligns with Safe System principles.

The Safe System Assessment Framework can be undertaken through application of the Safe System matrix. The Safe System matrix assesses different major crash types (those identified as the predominant contributors to fatal and serious crash outcomes) against the exposure to that crash risk, the likelihood of it occurring and the severity of the crash should it occur. The basic structure of the framework is provided in Table 4.2.

Appendix B provides an overview on how to complete the Safe System assessment framework.

The matrix highlights that a safe road environment is dependent on the exposure, likelihood and severity of crashes.

To reduce the exposure, likelihood and severity of crashes road practitioners need to implement to various degrees (the greater the degree of implementation the safer the road environment) all or a combination (the more that can be implemented the safer the road environment) of the following:

- Separate conflicting elements – physically separate the road users in the road environment so that road users are less exposed to conflicting elements, including other road users.
- Maintain control – ensure road users remain in control of their vehicles in accordance with the function of the road, with the road environment hazards controlled to reduce the likelihood of elements conflicting with one another. Maintaining control can extend to road user information management, to ensure that the appropriate information is relayed to the driver to ensure drivers have the best ability to maintain control.
- Speed management – reduce the severity outcome of crashes by reducing the energy exchange of two conflicting elements.
- Protecting road users – reduce the severity outcome of crashes by protecting the road users using energy absorbing devices in vehicles or the road environment.

Table 4.2: Safe System assessment framework for infrastructure projects

	Run-off-road	Head-on	Intersection	Other	Pedestrian	Cyclist	Motorcyclist
Exposure	AADT; length of road segment	AADT; length of road segment	AADT for each approach; intersection size	AADT; length of road segment	AADT; pedestrian numbers; crossing width; length of road segment	AADT; cyclist numbers; pedestrians	AADT; motorcycle numbers; length of road segment
Likelihood	Speed; geometry; shoulders; barriers; hazard offset; guidance and delineation	Geometry; separation; guidance and delineation; speed	Type of control; speed; design; visibility; conflict points	Speed; sight distance; number of lanes; surface friction	Design of facilities; separation; number of conflicting directions; speed	Design of facilities; separation; speed	Design of facilities; separation; speed
Severity	Speed; roadside features and design (e.g. flexible barriers)	Speed	Impact angles; speed	Speed	Speed	Speed	Speed
Additional Safe System components							
Pillar	**Prompts**						
Road user	Are road users likely to be alert and compliant? Are there factors that might influence this? What are the expected compliance and enforcement levels (alcohol/drugs, speed, road rules, and driving hours)? What is the likelihood of driver fatigue? Can enforcement of these issues be conducted safely? Are there special road uses (e.g. entertainment precincts, elderly, children, on-road activities on motorcyclist route), distractions due to environmental factors (e.g. commerce, tourism), or risk-taking behaviours?						
Vehicle	What level of alignment is there with the ideal of safer vehicles? Are there factors which might attract large numbers of unsafe vehicles? Is the percentage of heavy vehicles too high for the proposed/existing road design? Is this route used by recreational motorcyclists? Are there enforcement resources in the area to detect non-roadworthy, overloaded or unregistered vehicles and thus remove them from the network? Can enforcement of these issues be conducted safety? Has vehicle breakdown been catered for?						
Post-crash care	Are there issues that might influence safe and efficient post-crash care in the event of a severe injury (e.g. congestion, access stopping space)? Do emergency and medical services operate as efficiently and rapidly as possible? Are other road users and emergency response teams protected during a crash event? Are drivers provided the correct information to address travelling speeds on the approach and adjacent to the incident? Is there reliable information available via radio, variable message sign (VMS) etc.? Is there provision for e-safety (i.e. safety systems based on modern information and communication technologies, C-ITS)?						

Source: Austroads (2016a).

These elements are discussed further below, however in general it is noted that when applying risk engineering concepts to the road environment, road safety engineers need to consider that the road user has a simple intention to travel from origin to destination. The task of road safety engineering is to assist the road user to remain in control and to provide a forgiving road environment when they are not.

The road network can be considered safer when road users are in control of their speed and direction (on their chosen path at a speed that does not lead to loss of control) and they are aware of other road users (to avoid conflict). Where awareness of other road users is restricted by capacity issues or by sight distances (relative to expected speeds), then modifications to the network and/or the imposition of additional controls such as signals or grade separation are required.

4.4.1 Separating Conflicting Elements

In the context of a safe road transport system, it is important to lessen the probability that potentially conflicting road users will enter into direct conflict with one another. This is done through separating conflicting elements. Separating the recipient from the hazard means providing sufficient space or distance, or a physical barrier, so that a moving vehicle is unlikely to hit another road user or object.

Different road users usually occupy different parts of the road. Cars, trucks, motorcycles and buses occupy traffic lanes. Pedestrians occupy footpaths by the side of the road. Bicycles may occupy their own off-road lanes, share paths with pedestrians, occupy their own on-road lanes or share lanes with cars, trucks and buses. Potential conflicts exist when bicycles share lanes with other road users. For example, a bicycle in the same lane as a car may be in the path of the car's kinetic energy. If the car is travelling faster than the bicycle, the car's kinetic energy can damage the bicycle rider. If the bicycle is in an on-road bicycle lane, then the potential for conflict is reduced. If the bicycle is on an off-road path, then the bicycle rider (the recipient) can be considered separated or isolated from the car (the hazard) but may present a hazard to pedestrians sharing the path. Similarly, pedestrians crossing a road are potentially in the path of oncoming vehicles. Even with traffic signals, where time separation of the same space is provided to allow pedestrians to cross the road, a potential conflict exists. If the driver does not stop at a red signal, then the car and pedestrian can occupy the same space at the same time, with damage (injury) occurring to the pedestrian. Pedestrian overbridges or underpasses remove the conflict by separating the pedestrians from the vehicles.

In situations where the conflict cannot be avoided, effort needs to be applied to ensuring drivers remain in control of their vehicles. Since pedestrians are very likely to cross roads at grade, drivers need to be suitably warned and informed of their presence, and guided and controlled to stop or give way at pedestrian facilities.

It is worth noting that although intersection layouts cannot avoid conflict points (unless roadways are grade separated), it is good practice to minimise the number of conflict points and/or eliminate high angles of conflict to ensure low relative speeds between vehicles. The use of roundabouts as opposed to four-way or T-intersections is one way of achieving this.

4.4.2 Maintaining Control

In the context of a safe road environment, this measure can be considered as keeping the road user on track with regard to route selection, speed, direction, and position on the road. In a road transport system, the controller of the vehicle is the driver. The driver has direct control of the vehicle in the road environment and may respond to external controls directing them on how to control their vehicle. External controls may include elements such as traffic signals.

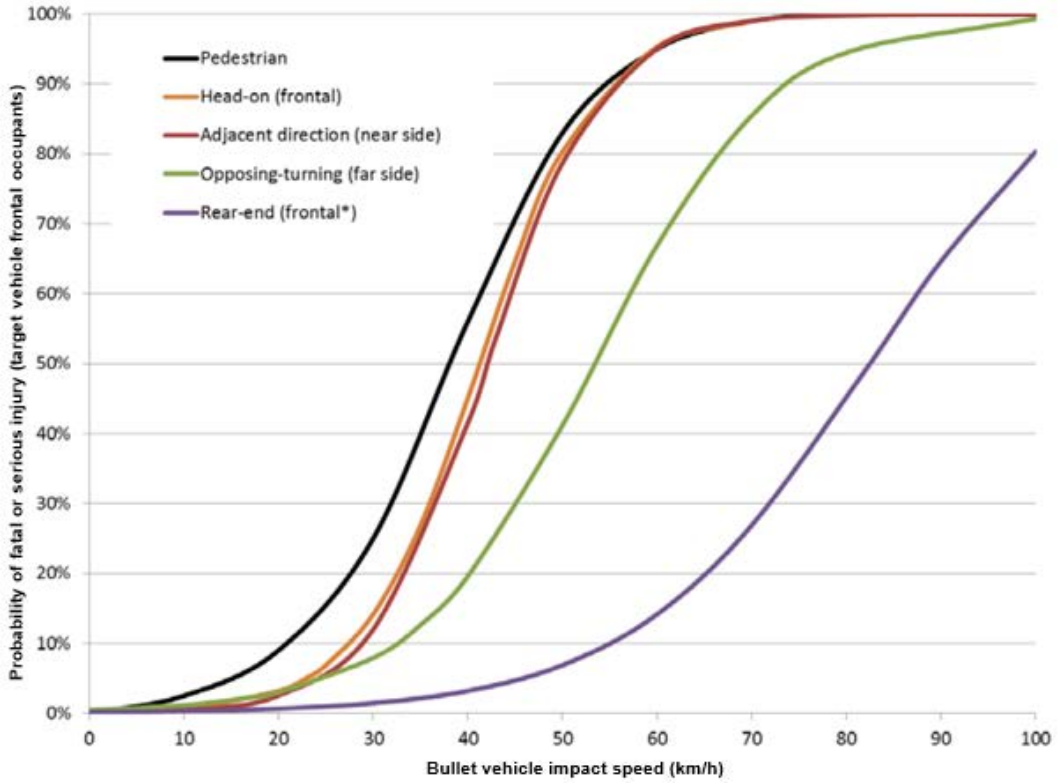
In a risk engineering context, most of the features defining a safe road environment listed in Table 2.1 are aimed at ensuring drivers maintain control of their vehicles. This is often described as crash avoidance.

Also included is the provision of a road environment which allows drivers to correct or recover from an initial loss of control – a road environment forgiving of road user error. If loss of control occurs, a safe road environment aims to ensure that the driver can recover control and continue their way. For example, provision of a sealed road shoulder provides additional space for swerve and recovery, with high levels of friction where it may be needed most. Unsealed shoulders can provide the same space, but not the same friction; they provide less friction at a point where a driver might be requiring more.

4.4.3 Speed Management

As outlined in Austroads (2016a) there are limits to the biomechanical tolerances of the human body under different crash scenarios. Speed management is at the core of the Safe System approach. A Safe System speed is defined as the maximum speed upon impact where the chance of death or serious injury is minimised or eliminated. This speed changes depending on the angle of impact and the road user type. Figure 4.1 outlines the FSI impact speeds for various crash types. It is acknowledged that the Safe System speeds presented are not definitive and therefore should be treated as indicative only as crash outcomes are dependent on the type and angle of the crash. The speeds shown in Figure 4.1 are also reflected in Table 4.3. The values in the table are indicative only and have been rounded to the nearest 5 km/h.

Figure 4.1: Fatal and serious injury risk based on impact speed for various crash types



** In rear-end crashes the frontal occupants of the bullet vehicle sustain greater risk of severe injury than those in the target vehicle.*
Notes: Bullet vehicle speed is the speed of the vehicle that hit the target. For head-on it is assumed that both vehicles are travelling at the same speed.

Source: Based on Austroads (2015h).

Table 4.3: Approximate critical impact speeds for common crash types

Crash type	Critical impact speed (km/h)*
Pedestrian-vehicle	20
Head-on	30
Adjacent direction	30
Opposing-turning	30**
Rear-end	55

** This is the speed of the bullet vehicle involved in the collision.*
*** Depending on the impact angle and the target (turning) vehicle speed, this value may vary.*

Source: Austroads (2015h).

Effective speed management requires investment in three main areas: engineering, education (including community education and engagement) and enforcement. In addition, emphasis is placed on the importance of cross-agency collaboration and ongoing engagement with research and best practice. Brief details with respect to the contribution that engineering, education and enforcement has on speed management are outlined below:

- Engineering – while speed management can be undertaken through applying speed limits only, outcomes are enhanced if the road environment is designed to naturally elicit an appropriate speed response. For example, long, wide, straight local streets lead to higher-speeds. Streets suitably altered by local area traffic management (LATM) treatments lead to lower-speeds. The same principles apply to highways. Curvilinear highways with appropriate radii curves may lead to lower, but not excessively slow speeds. Straight highways may lead to higher-speeds. Long, straight sections of highways also give rise to isolated curves, which may present problems for drivers.
- Education – education is an important element of speed management. Education helps to communicate the inherent risks involved in speeding and allows road users to understand the importance of speed management and road safety, and how the measure seeks to contribute to these goals. Education should also include details with respect to enforcement (see below). This should include outlining the penalties associated with disobeying the speed limit, and the speed enforcement measures undertaken to discourage drivers.
- Enforcement – to maximise the effectiveness of speed management engineering features, enforcement along with penalties for violating any regulatory control is required to discourage drivers from breaking the regulatory control (i.e. speed limit). This is intended to reduce the number of drivers exceeding the limit and consequently lower the mean and 85th percentile speeds.

The *Guide to Traffic Management Part 5: Road Management* (Austroads 2017e) provides guidance on the risk-based selection of speed limits for different road categories and functions.

4.4.4 Protecting Road Users

Raising the damage threshold of the road user amounts to limiting the amount of energy that is directly transmitted to road users in the event of a crash. Typical examples are helmets and protective clothing for motorcycle riders. Vehicles which better protect occupants in impacts effectively raise the energy level (and crash forces) at which life-threatening injury is experienced.

An errant vehicle leaving the roadway can be considered as a protective package encasing the vehicle occupants. The vehicle provides significant protection from impact with a roadside object, but if the energy level is great enough, the impact can injure the occupants.

The limited protection offered by vehicle systems also has implications for the frangibility of road and roadside features, for example, frangible light poles and signposts, and roadside plantings that are soft and yielding. In conjunction with vehicle design, road environment features can be provided which protect occupants, not by raising the damage threshold, but by ensuring that damage thresholds are not exceeded. That is, the combination of road design, traffic management, and vehicle design work together to ensure crash forces are tolerable to occupants.

4.5 Road Safety Engineering Strategies

A road environment must meet basic objectives of mobility, efficiency, safety, and amenity. This is achieved by providing a suitable road network and managing it appropriately. Safety management of the road network is aimed at maximising the safety outcomes of road and traffic management activities. This requires both appropriate technical measures and suitable management processes to ensure that safety benefits are achieved.

The safety factor of all capital works projects should be well understood to enable better decision making on where and how to plan programs. This includes understanding how well proposed works translate Safe System research and knowledge into practice and how well it implements Safe Mobility (refer to Section 2.4).

The basic intended outcome of a road environment safety program is a safer road and traffic environment through greater consideration of safety issues in the planning, design and development of the road network and traffic management facilities. This approach should include safety conscious planning activities, a clear safety focus in design activities, various investigative and analytical activities, and a strong component of continual monitoring and assessment. For these, good quality information and comprehensive crash databases are essential to make informed decisions.

In addition to the fundamental practice of consistently applying relevant standards and guidelines (Section 4.3.2), a road environment safety program is typically characterised by the following main elements:

- database development and management
- hazardous location identification and analysis
- crash location investigation and countermeasure development
- remedial treatment and evaluation
- road safety audit and network safety assessment.

These activities are dealt with in detail in the *Guide to Road Safety Parts 6, 7, 8, and 9* (Austroads 2009a, 2006a, 2015k, 2008b). From a traffic management perspective, the important strategic approaches can be listed as follows:

- ensuring safety in planning and design
- treating known hazardous locations
- identifying safety deficiencies in the road network
- treating identified deficiencies.

4.5.1 Ensuring Safety in Planning and Design

The essential concept in this approach is the prevention of safety deficiencies using procedures focussed specifically on safety aspects during the planning and design stages of a road-related project.

The basic procedure is the road safety audit process, presented in detail in the *Guide to Road Safety Part 6* (Austroads 2009a). The road safety audit process is a proactive, formal, systematic process for identifying from first principles any safety deficiencies in a project and indicating likely directions for remedial amendments to the plans or designs. It is an essential tool in road safety engineering.

Application of this concept in the planning of land-use developments is often referred to as safety-conscious planning. This is a proactive approach to the prevention of crashes and unsafe conditions by integrating safety considerations for all road users into planning processes at all levels. An informative overview of the approach is given in Brindle (2001). The principle is that the planned physical environment should not contain or encourage situations with unacceptable risk of injury from the traffic it generates. Safety-conscious planning seeks to integrate safety engineering into the earliest planning phases of land-use developments and transport networks to minimise exposure, risk, and conflicts. Note that safety requirements are often different for different road users.

Austroads (2009a) outlines the use of the safety audit process in road project feasibility studies and its potential for use in the land-use development approval process. Further safety considerations in traffic management associated with land-use developments are outlined in the *Guide to Traffic Management Parts 7 and 12* (Austroads 2015b, 2016h).

The *Guide to Traffic Management Part 12: Traffic Impacts of Developments* (Austroads 2016h) outlines how land-use developments can impact the safety of roads. The Guide highlights that developments have the potential to cause the following impacts:

- excessive volumes
- more conflict points
- excessive speeds.

These impacts, because of developments, have the potential to impact on safety of the adjacent and nearby roads, unless mitigated through appropriate safety treatments.

A traffic impact assessment is used to identify the issues caused by the development and identify treatments to address them. Some sample treatments, as identified in the *Guide to Traffic Management Part 12 (*Austroads 2016h), and used to address safety issues include:

- additional through traffic lanes and/or turn lanes
- additional arterial, service or local roads
- new intersections
- new signalisation or changes to the phasing of signals and signal co-ordination where new intersections are implemented
- new medians, closed median breaks, new turning lanes
- modified driveways
- rumble strips for road edge delineation
- guardrails on embankments
- acceleration and deceleration lanes
- provision, relocation or upgrading of bus/tram stops and services
- modifications to parking arrangements (e.g. removal of parking near the new driveway(s) or more extensively to provide better capacity, safety or operating conditions on approach roads)
- new, relocated or upgraded footpaths, bicycle paths and shared paths
- pedestrian and cyclist crossing facilities (e.g. signals, refuges)
- pedestrian and cyclist grade separations
- pedestrian fencing.
- new, relocated or upgraded bus stops, bus bays and bus priority measures
- bicycle lanes.

In the road and traffic design context, safety aspects should be addressed as early as possible. The road safety audit process provides the mechanism to ensure that this is done. The earlier in the design process a road safety audit can be undertaken, the better (and more financially efficient) the result will be. If an inappropriate concept or treatment (i.e. one with inherent safety problems in the particular context) is chosen at the feasibility stage, it is difficult and often impossible to remove safety problems at a later design stage or once traffic is using it. Early auditing can also lead to the early elimination of problems and, consequently, minimisation of wasted design time at later stages. Broader safety considerations should include issues such as pedestrian security and separation of transport modes.

Ensuring safety in planning and design also extends to road agencies management of the roadside. There is increasing demand to place roadside advertising along the road. Road agencies need to manage the approval of roadside advertising to ensure that it does not have a detrimental impact on driver workload. Road agencies need to make an assessment of the safety risk prior to approval. Discussion on driver workload and the impact roadside advertising may have on driver workload is contained in Section 4.5.4.

4.5.2 Treating Known Hazardous Locations

The essential concept in this approach is the treatment of deficiencies at locations with undue crash experience, together with maintaining the safety features of the road network.

The basic technique is that of using remedial countermeasure treatments which address the nature of crashes as revealed through structured investigations at identified locations.

Such crash investigation programs are reactive, based on crash history, and therefore require databases of sufficient scope and quality to enable meaningful analysis. The process seeks to identify and understand factors contributing to past events, and to identify appropriate remedial treatments for correcting deficiencies in the existing road environment.

The crash investigation and treatment process is presented in detail in the *Guide to Road Safety Part 8* (Austroads 2015k).

4.5.3 Identifying Safety Deficiencies in the Road Network

Proactively identifying safety deficiencies in the road network is critical to implementing a Safe System as it can assist road agencies in addressing these deficient locations before a fatal and/or serious injury crash occurs. The *Guide to Road Safety Part 7: Road Network Crash Risk Assessment and Management* (Austroads 2006a) provides an overview of risk assessment and risk management in context of roads and the Safe System.

The *Guide to Road Safety Part 7* (Austroads 2006a) provides examples of risk assessment strategies used by road agencies. The *Guide to Road Safety Part 7* (Austroads 2006a) outlines how potential safety deficiencies in the road network can be identified proactively through undertaking safety assessments.

While there may be various approaches, they all generally acknowledge that humans are fallible and make errors of judgement while driving. The approaches can assist road practitioners in assessing the road and aiding them in identifying risk, hence working towards eliminating or mitigating those risks. Some common tools used by road practitioners to identify safety deficiencies include:

- road safety audit
- Road Assessment Programs (RAP): including AusRAP and KiwiRAP
- Australian National Risk Assessment Model (ANRAM)
- Austroads Road Safety Engineering Toolkit
- risk based assessment of curves (e.g. advisory speed program).

Some of these are outlined below.

Road safety audit

The road safety audit process can be applied to the existing road environment to identify safety deficiencies or hazards. A road safety audit of an existing road – as distinct from safety audits of new project designs – is a proactive approach aimed at identifying any feature of a road which could contribute to future crash occurrence or unnecessary crash consequences. Unlike crash investigation procedures, the road safety audit approach does not provide a targeted analysis of crash characteristics at that location which leads to specific remedial treatment. Application of the road safety audit process to existing roads is presented in the *Guide to Road Safety Part 6* (Austroads 2009a). The use and condition of a road can change over time as well as the adjacent land use. This can generate different traffic volumes, a different mix of traffic, different roadside environments, and different and/or new traffic conflicts. Regular audits of existing roads allow emerging road safety hazards to be identified before they result in crashes.

Road Assessment Programs (RAP)

The Australian Road Assessment Program (AusRAP) and NZ version KiwiRAP are based on the International Road Assessment Program (iRAP). AusRAP and KiwiRAP use four complementary methods or protocols for assessing the safety of roads. These include Risk Mapping, Performance Tracking, Star Ratings and Safe Road Investment Plans (SRIPs).

Risk Maps use detailed crash data to illustrate the actual number of deaths and injuries on a road network. Performance Tracking enables the use of Star Ratings and Risk Maps to track roads safety performance and establish policy positions. Star Ratings provide a simple and objective measure of the level of safety provided by a road's design.

The program uses the attributes to calculate star ratings for a road network to reflect the level of safety, where five stars reflects the safest road in the model and one star reflects the least safe road in the model. AusRAP provides an investment plan to improve the star rating of roads or length of roads within a network, thereby improving the level of safety within a network. KiwiRAP does not have an investment plan functionality per se, but the KiwiRAP Analysis Tool (KAT) allows an analyst to test the impact of various treatments. SRIPs draw on proven road improvement options to generate affordable and economically sound infrastructure options to address road safety. ANRAM which has been built based on AusRAP and KiwiRAP is similar.

Details of the relationships between AusRAP/KiwiRAP and ANRAM are tabulated in Table 4.4.

Table 4.4: The relationship between AusRAP/KiwiRAP and ANRAM

AusRAP/KiwiRAP	ANRAM
AusRAP is the Australian Road Assessment Program and KiwiRAP is the New Zealand Road Assessment Program. They are local applications of the International Road Assessment Programme (iRAP).	Australian National Risk Assessment Model.
AusRAP/KiwiRAP provide a consistent approach to assessing risk through the provision of star rating of roads. The RAP programs also provide guidance on improvements that may be made to reduce the likelihood of road crashes.	ANRAM builds on the AusRAP approach. It uses AusRAP algorithms at the core of the Risk Assessment Module in the calculation of ANRAM Risk Scores. ANRAM then uses Safety Performance functions to predict the frequency of FSI crashes, which is supplemented with observed FSI crashes to determine expected FSI crashes. Performance of different user-defined treatment scenarios may be compared.
AusRAP is managed by the Australian Automobile Association and state and territory motoring clubs. KiwiRAP is a joint initiative involving the New Zealand Automobile Association, New Zealand Transport Agency, Ministry of Transport, New Zealand Police and the Accident Compensation Corporation (ACC).	Development of ANRAM was funded by Austroads and guided by Australian road agencies and motoring clubs.
AusRAP/KiwiRAP uses road attributes to calculate crash risk and star ratings for roads.	ANRAM combines the predicted and observed severe crashes for each road section to produce an estimate of FSI crashes across the given road network.
AusRAP/KiwiRAP's outputs are focused on star rating roads and recommending an improvement program to improve star ratings.	ANRAM has a greater focus on reporting future crash risk in terms of expected FSI crashes. ANRAM outputs are focussed on defining priorities for Austroads road agencies to minimise FSI on the road. ANRAM also provides greater control for users in treatment development.
AusRAP/KiwiRAP star ratings are a useful and easy-to-understand tool for communicating road safety risk to the community.	ANRAM is useful for road agency practitioners when assessing the safety benefits of alternative treatment scenarios.

Australian National Risk Assessment Model (ANRAM)

ANRAM provides Australian road agencies with a system to implement a nationally-consistent risk-based road assessment program to identify road sections with the highest risk of severe crashes (ARRB Group 2014). ANRAM is a nationally agreed approach that has built on existing Australian and international risk-based road safety programs, such as AusRAP, NetRisk, iRAP and KiwiRAP, to create a system directly relevant and applicable for Australian state, territory and local road agencies. Development of ANRAM was funded by Austroads and guided by Australian road agencies.

ANRAM provides a mechanism for identification, measurement and reporting of severe crash risk. Risk estimation is driven by relative safety performance of road infrastructure, traffic speed, flow and potential for vehicle conflicts. Severe crash history is used to supplement the predicted results and account for road user-related risk. Road sections may be ranked based on individual risk and collective risk.

ANRAM supports a Safe System approach by focussing on the risk of fatal and serious injury (FSI) crashes. It uses a systematic and consistent methodology based on local and international research to identify, compare and prioritise severe crash risk.

AusRAP/KiwiRAP and ANRAM both assist in formulating road safety engineering treatment programs, however ANRAM gives users greater control over treatment selection.

ANRAM comprises four modules:

- Risk Assessment Module (RAM) – calculates the relative risk of different types of FSI crashes because of road features, speed and levels of potentially conflicting traffic. ANRAM uses AusRAP algorithms at the core of the module.
- Crash Prediction Module (CPM) – uses safety performance functions to predict the frequency of FSI crashes given road section length, traffic flow, road infrastructure and speed, over a typical five-year period.
- Crash Validation Module (CVM) – computes expected FSI crashes by comparing and combining predicted FSI crashes (from the CPM) and observed FSI crashes to produce ANRAM FSI crashes. The ANRAM FSI crash estimates represent a stable estimate of severe crash risk for a given road network or route.
- ANRAM Toolkit – enables users to carry out investigations of severe crash risk on the road network and analysis of potential treatment programs.

Austroads Road Safety Engineering Toolkit

As outlined in the *Guide to Road Safety Part 8* (Austroads 2015k), the Road Safety Engineering Toolkit has been developed by Austroads in a web-based application which is designed to help select low cost road engineering countermeasures.

The toolkit can be used to identify countermeasures through the determination of the crash problem (such as head-on or run-off-road crashes) or by selecting a road safety issue (such as inadequate linemarking at signalised intersections). Many treatment options are given along with where the selected treatment should or should not be used, the benefits, approximate costs and the life of the treatment, alternative methods to be taken into consideration, and referencing of further information. Use of the tool can aid practitioners in providing for safe roads in recognition of achieving a Safe System.

Risk based assessment of curves (e.g. advisory speed program)

Risk based assessments can be undertaken in situations such as the assessment of curve risk. An example of this is determining the advisory speeds on horizontal curves using a ball bank indicator as described in AS 1742.2-2009 or alternatively using an electronic accelerometer (such as the Vericom or CurveRite systems).

Advisory speeds using the ball bank indicator are determined through trials of different speeds and measuring the ball bank angle. The ball bank angle is the deflection of the 'ball' caused by the centripetal force acting on the vehicle. This is the change from the plane perpendicular to the horizontal. This shows how much the vehicle rotates as it goes around the corner. Generally, the faster the vehicle goes the more the vehicle tilts. The angle and the speed used to calculate the angle are then inputted into the chart, which indicates the advisory speed.

Like the study procedure for the ball bank indicator, the use of an electronic accelerometer involves a vehicle driven through a curve at a constant speed, following the radius of the curve as closely as possible. The accelerometer stores the data allowing the test to be done with one person (i.e. the driver) as a second person is not required to read the equipment. The accelerometer records the maximum lateral gravitational force and the speed at which that force occurred for each run. The advisory speed of the curve is set at the highest speed that can be driven without exceeding a specified, comfortable lateral acceleration.

Once the advisory speed is determined, it can then be signposted in advance of the curve to inform approaching motorists of the advised speed to negotiate the curve. This can assist motorists in understanding what speed to approach the curve to avoid losing control and goes towards delivering a Safe System.

Determining what speed should be posted as an advisory speed using either the ball bank indicator or the electronic accelerometer should be undertaken in a consistent manner in terms of which device is used and how the device is used. This is to assist the road user expectations of the upcoming curves (based on how previous curves have been signposted) and to adjust their travel speed accordingly.

4.5.4 Managing Driver Workload

When implementing road safety engineering strategies, either on a new road environment or amending an existing road environment, care should be taken to ensure that driver workload is managed, as inappropriate driver workload may increase the potential for crashes. Driver workload can be managed through road design, by having sufficient spacing between sections of weaving, ramps and key decision points etc. to avoid overloading the driver. Guidelines on the design of the road to avoid driver overload are contained in the *Guide to Road Design* series and the *Guide to Smart Motorways* (Austroads 2016i).

The amount of information with respect to the road infrastructure and traffic conditions/behaviour that is expected to be processed by the driver also needs to be effectively managed to avoid overloading the driver.

Too much information can lead to the driver not having the capacity to comprehend the signs. Too little information on the other hand may result in the driver not being adequately aware of aspects of the road that the driver should be aware of.

Managing driver workload requires:

- taking into consideration the information to be conveyed
- determining whether the communication is effective and necessary
- determining the potential for overloading the driver and the desire to minimise roadside structures used to support signage. Minimising roadside structures is important in achieving a safe road environment and therefore a Safe System.

Balancing the need to convey adequate information with managing driver workload has been considered for some time. Guidance on managing driver workload is well established and covers elements such as:

- Location and placement of signs – the location and placement of signs relative to the driver's line of sight and specific decision point are important so that the signs may be identified, read and understood by the driver easily and quickly. This will ensure that the driver's attention can remain on the road and the driver may take the appropriate action in response to the sign.

- Spacing of signs – the spacing of signs impacts on the amount of information being conveyed to drivers. Care should be taken so that drivers are reminded of the message being conveyed but not so much that it causes signage clutter and potentially signage to be ignored or obscured by other signs.
- Legibility of signs – the legibility of the sign impacts on the length of time it takes a driver to read and comprehend the message. Care should be taken to ensure that the signage is clear and can be read easily and quickly by drivers of vehicles passing the sign, so that their attention can remain on the road.
- Contents of signs – the contents of the sign impacts on the length of time it takes a driver to read and comprehend the message. Care should be taken so that the message can be quickly read and understood by drivers of vehicles passing the sign, so that their attention can remain on the road.
- Collocation of signs – collocation of signs with other signs, variable message signs which may contain multiple screens of information, takes longer to read and adequately comprehend, therefore drawing more attention to them. Collocation of VMS with static signs is not preferred. However, dual collocation of lane use management system (LUMS) with VMS or dual collocation of LUMS with static direction signs is considered acceptable. Triple collocation (i.e. collocating with a static sign and LUMS) is not preferred but acceptable to trial if constraints require it.

The *Guide to Traffic Management Part 10: Traffic Control and Communication Devices* (Austroads 2016e) discusses these aspects with respect to road related signage and line marking in the road environment.

In addition, there are distractions internal to the vehicle and distractions along the roadside that have the potential to impact on driver workload and therefore road safety. As this Guide relates to the road environment, the following discussion will apply to distractions within the road environment such as roadside advertising. However, the following principles would apply to in-vehicle distractions. As discussed in Austroads (2013d) the key issues with respect to safety associated with roadside advertising include:

- Potential for capturing attention involuntarily – as the function of roadside advertising is clearly to capture attention, this is undesirable from a road safety, Safe System, perspective if it results in attention being diverted from driving.
- Mental workload – as humans have limited capacity for processing information simultaneously there is the potential for the processing of roadside advertising to interfere with the processing of information critical for safe driving.
- Gaze direction – safe driving requires that drivers are looking in the appropriate direction to maximise their information gain about critical aspects of the driving environment. Clearly if they are looking in a direction that is well outside the visual envelope of normal driving there is the risk that critical road-related information will be missed. Therefore, advertising is best place in the line of sight of drivers, but without obscuring or backgrounding critical road-related signage, signals or infrastructure.
- Road environment – roads which have a high crash rate or are classified as having a high risk of crashes should not be subject to features such as roadside advertising which may distract the driver from their task and therefore increase the risk of a crash.

Various jurisdictions have guidelines pertaining to roadside advertising, and practitioners should refer to their jurisdictional guidance. However, Austroads (2013d) provides guidance with respect to the design and placement of signs to achieve a safe road environment. Guidance from Austroads (2013d) is repeated in Commentary 1.

See Commentary 1

4.6 Safety Management Systems

Road safety engineers should ensure that the road network is designed and treated from a safety perspective. The operation of the road network needs to be adequately monitored, measured, and managed to meet targeted safety performance levels. These targets in turn need to be soundly based on well-developed road safety strategies in the road agencies concerned.

There is a need to incorporate all such principles, tools, techniques, and strategies systematically into a management framework aimed clearly at achieving demonstrable results in terms of savings from crash and casualty reduction. A systematic or structured approach for safety management is indicated.

Such a safety management system approach has been pursued effectively (see for example NZ Transport Agency (2005)). This approach generally requires that the following steps and processes be adopted:

- a strategic road safety direction and vision for the agency, including the stakeholder partnerships needed to develop it, and a strategic plan for achieving a reduction in crashes
- a road safety engineering toolbox for delivery, including a program for pursuing
  - formally adopted standards and guidelines
  - database development and collection activities
  - crash investigations and analysis
  - safety audits
  - remedial treatments
- arrangements whereby relevant technical expertise is involved in applying this guidance
  - this means that road agency personnel or contractors engaged in road safety engineering matters should have the relevant technical expertise
- policies and management procedures that ensure the standards, guidelines and associated activities are implemented in a systematic and consistent manner, and that clear responsibilities are allocated for the road safety engineering processes to be used
- a continuous improvement and monitoring regime to ensure best practices are in place and are being delivered.

A structured safety management system approach such as this provides an ideal context for an effective risk management process as described in the *Guide to Road Safety Part 7* (Austroads 2006a).

Further development of the safety management system and safer journeys strategy by using the Safe System approach in New Zealand can be found in Ministry of Transport (2014).

5. Safety Engineering of the Road Environment

5.1 Principles and Elements

Managing safety in the road environment means managing the risk that injury will occur, whether it arises from the behaviour of road users, the performance of vehicles or the characteristics of the road environment. Making roads safer means reducing the risk. This applies to all road users – vehicle drivers, riders, passengers, cyclists, and pedestrians.

Safe operation of the road and traffic system is a fundamental goal for road designers and traffic engineers, who have a prime responsibility for addressing the safety factors related directly to the road environment itself.

As outlined in Section 4.4 the risk engineering concept used to reduce safety risk to move towards a Safe System include:

- separate conflicting elements
- maintain control
- managing speed through speed management
- protect road users.

Pursuit of these principles is reflected in the various parts of the *Guide to Traffic Management*, the *Guide to Road Safety* and the *Guide to Road Design*. The tools of traffic engineering are used in addressing these issues, in seeking to provide the warning, information, guidance, control, or clearance necessary for a safer road environment. When the implementation of these principles is not possible, practical or sustainable, practitioners need to review and understand the risks, and make sure the consequences are acceptable.

The road environment can be broken down into the elements illustrated in Table 5.1, each of which has the potential to influence the safety of traffic operation within that environment.

Table 5.1: Elements of the road environment

Road structure	Geometry (horizontal and vertical alignment) Cross-section (lane widths, formation widths, crossfall and superelevation) Pavement (friction, roughness and rutting)
Roadside	Natural features (terrain, watercourses and trees) Introduced features (cuttings, embankments, culverts, drainage pits, poles, barriers, pathways and cycleways)
Intersections	At-grade, grade-separated interchanges, heavy and light rail crossings
Traffic facilities	Traffic controls (speed limits, traffic signals, marked crossings, medians, kerb extensions and humps) Intersection control (traffic signs, roundabouts and priority control) Signs (regulatory, warning, directional and information) Markings (longitudinal and transverse lines, arrows and numerals) Delineation (lines, guideposts, reflectors and raised pavement markers)
Road lighting	Route lighting (routes, intersections and tunnels) Local street and pathway lighting

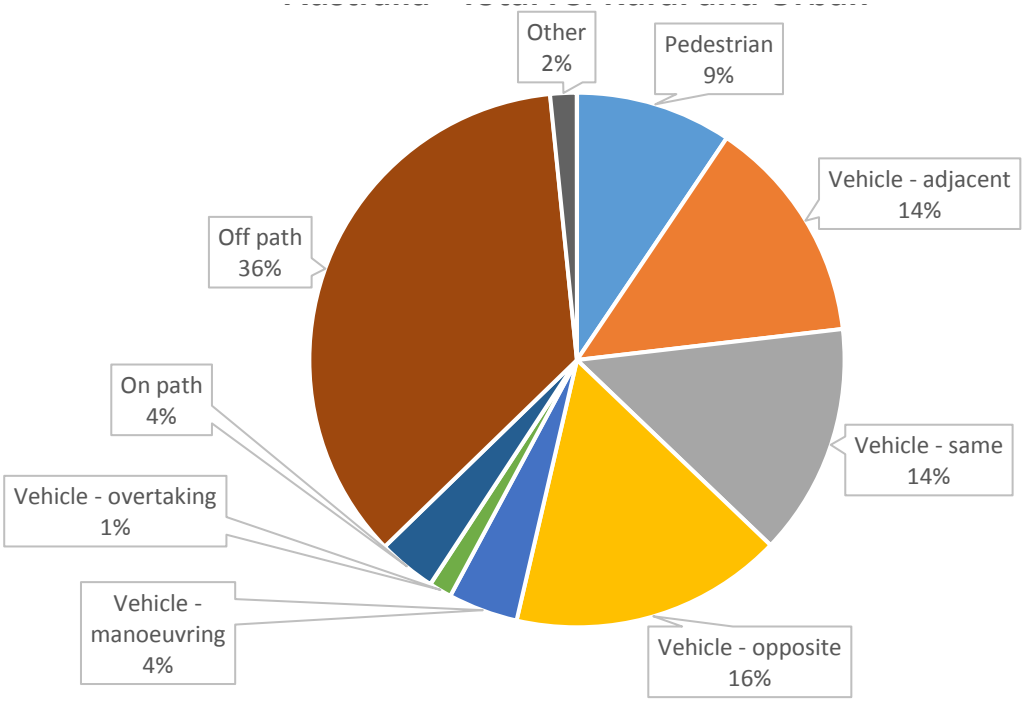
Australian and New Zealand Standards, and Austroads guidelines – particularly those noted in Section 1.3 – have been developed to guide practitioners in designing, constructing, installing, and maintaining these elements of the road network.

The relationship between the basic elements of the road environment and the characteristics of a safe road environment (Section 2) are presented in the tables in Appendix A. The cells of the matrix identify the relevant standards and guidelines. Some important points concerning the contribution of the various elements to a safer road environment are presented in Section 5.2.

5.2 Managing the Elements

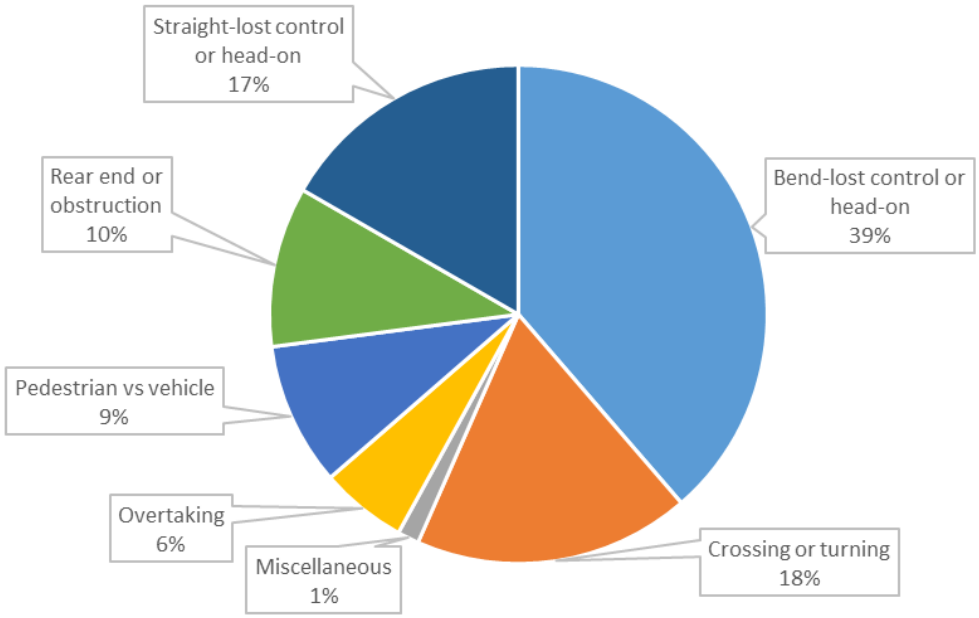
Austroads (2015f) provides an overview of the fatal and serious injury (FSI) crashes in urban and rural road environments by crash type and for Australia and New Zealand. A summary of the results is presented in Figure 5.1 and Figure 5.2. Further graphs that form the basis of the graphs presented in Figure 5.1 and Figure 5.2 are outlined in Appendix C.

Figure 5.1: Fatal and serious injury crashes in rural and urban Australian environments by crash type, 2006–10



Source: Based on data presented in Austroads (2015f).

Figure 5.2: Fatal and serious injury crashes in rural and urban New Zealand environments by crash type, 2006–10



Source: Based on data presented in Austroads (2015f).

The results of the study indicate that off-path crashes were associated with the greatest percentage of FSI crashes in both Australia and New Zealand.

Austroads (2016f) and Austroads (2014c) provide information on the effectiveness of various treatments such as signs, pavement markings, intersection treatments, road delineation and segregation etc.

However, more broadly, road agencies should look at managing the various elements of the road to deliver a Safe System. A critical element of a Safe System is delivering a safe road. The following sections (Section 5.2.1 through to Section 5.2.14) discuss the various road elements that need to be managed to produce a safe road. These include: road alignment, cross-section, pavement features, roadsides, intersections and crossings, traffic controls, traffic signals, traffic signs, markings and delineation, road lighting, roadworks, non-roadwork incidents and on-road public transport. Speed management, as discussed in Section 4.4.3, is not identified as a safe road environment feature. However, as speed management comprises the controlling of the speed it is primarily catered for through the various road environment elements but through traffic controls, signs and markings.

5.2.1 Road Alignment

The alignment of a road, its combination of horizontal and vertical curves plays an important part in influencing a driver's speed and positioning of a vehicle on the road. The road alignment informs the road user of the way ahead. A poor combination of horizontal and vertical curves can be misleading and lead to driver error, which may result in vehicles running off the road or into oncoming traffic. Where vehicles run off the road then the roadside, as discussed in Section 5.2.4, has a direct influence on the crash outcome (i.e. whether the errant vehicle hits an object or can regain control).

For example, locating a horizontal curve after a crest can lead to an ambiguous situation for the driver. This can be avoided by ensuring the horizontal curve is matched with the crest, commencing before, not at or after, the crest.

Similarly, a curve of decreasing radius immediately after a crest could surprise drivers, leading to vehicles running wide – either off the curve or into oncoming traffic.

These situations may be addressed with appropriate signs and delineation, but this should be the approach of last resort. It is better to implement geometric improvements, and preferably to avoid such situations in the design phase.

The *Guide to Road Design Part 3* (Austroads 2016g) provides guidance on appropriate geometric design.

5.2.2 Cross-section

The cross-section width enables the provision of a forgiving road environment. Sealed shoulders and wide lanes (on two-lane, two-way roads) provide more space for avoiding minor tracking errors which can lead to crossing the centreline or running off the road.

The *Guide to Road Design Part 3* (Austroads 2016g) provides recommended width for various urban and rural lane types and shoulders. Lane width that are both less than or more than the recommended width can pose safety issues: The issues associated with narrow lane widths are obvious as it can reduce the space between adjacent vehicles. However, the issues associated with widths wider than the recommended width is less clear and practitioners should be wary of providing extra wide lanes. Some research has shown a correlation between the width of lanes and crashes with various factors contributing to the crash outcome, for example:

- Lane widenings were found to reduce crash rates in curves, but to increase crash rates on straight sections (Tsyganov, Machemehl & Warrenchuk 2005 cited in Elvik et al. 2009). A simultaneous increase of lane and shoulder width in curves has been found to increase crash rates (Hanley, Gibby & Ferrara 2000 cited in Elvik et al. 2009).
- Widening of lanes on straight sections has been found to increase crash rates (Tsyganov, Machemehl & Warrenchuk 2005 cited in Elvik et al. 2009).
- Extra-wide lanes, wide enough to allow for overtaking while there is oncoming traffic has been found to increase the speed of vehicles (Frost & Keller 1990, Frost & Morrall 1998 cited in Elvik et al. 2009). This may not always be desirable for the road environment and therefore where not desirable, not in alignment with the Safe System.
- Wider lanes may result in a nett increase in road width. In an urban environment, this results in a longer distance for traffic to cross, resulting in increased exposure. With increased exposure, the crash rate increases.

Wider sealed shoulders provide more space for emergency manoeuvres without the road user experiencing a lower friction supply, and provide space for vehicles to stop well clear of the traffic lanes. Narrow shoulders with emergency lay-bys at regular intervals are less likely to provide the same opportunities. Wider sealed shoulders also provide more durable pavement and minimise moisture ingress into the pavement edge near the outer wheel path. Austroads (2015c) highlighted the safety reasons for sealing and reported that provision of wider sealed shoulders reduces the risk of casualty crashes along rural roads.

Wider cross-sections on two-lane two-way roads also provide the opportunity for wider centrelines, or painted median treatments, which can provide greater lateral clearances between vehicles in opposing traffic streams.

As part of the cross-section design, traversable batter slopes and clear zones free of non-frangible objects allow for road users who run off the road to regain control or stop without colliding with hazardous roadside objects. Austroads (2014b) notes that for clear zones the proportion of the casualty run-off-road crashes in which hazards were struck decreased as the clear zone width increased. However, it was also showed that as the clear zones increased the proportion of casualty rollover crashes also increased.

Austroads (2016g) provides guidance for appropriate road cross-sections. Austroads (2015c) proposes possible updates for the design of rural road cross-sections aimed at reducing the casualty crash risk on rural roads.

5.2.3 Pavement Features

The friction of the road pavement enables vehicles to maintain control both when proceeding through a grade or curves, or when needing to reduce speed on approaches to traffic controls.

Pavement friction can be reduced by factors such as the polishing of pavement surfaces and wet surfaces. Some pavement materials are more prone to polishing than others, and some surfaces which perform well under dry conditions suffer marked friction loss under wet conditions. The provision of high quality surface drainage systems with appropriate maintenance eliminates water ponding and reduces adverse impacts.

Pavement friction can also be significantly reduced by the presence of loose aggregate, which can be dragged onto the roadway from vehicles exiting unsealed driveways or side roads. If the side road is on a curve, then loose aggregate will be present where vehicles demand lateral friction. A similar situation may also occur when excess aggregate is not removed from the road surface during or after roadworks. Loose aggregate is more hazardous for motorcycles than it is for cars, since there is no additional wheel or tyre on an axle to retain some traction.

Regular monitoring of pavement condition (e.g. via SCRIM for friction) and implementing appropriate maintenance or resealing programs based on the *Guide to Asset Management Part 5* (Austroads 2009b) allows pavement friction and smoothness to be maintained at an appropriately safe and forgiving level.

5.2.4 Roadsides

In addition to the cross-section width, which aids in providing a forgiving road, the location and type of objects located along the roadside also impact on the safety of the road. For this reason, incidents with a potential for vehicles to leave the road surface need to be considered in the design and management of the roadside environment, so that collisions with objects on the roadside do not lead to injuries that are needlessly severe. A suitably designed and managed roadside environment can compensate road users for any errors or loss of control.

The *Guide to Road Safety Part 9* (Austroads 2008b) and the *Guide to Road Design Parts 6 and 6B* (Austroads 2010, 2015a) provide detailed guidance on the management of roadside hazards and the appropriate design of roadsides. Primary objectives include:

- providing a road environment that reduces the likelihood of vehicles running off the road
- providing a roadside environment that is free of unnecessary hazards
- providing a road environment that reduces the severity of injuries should an incident occur.

Roadside objects presenting hazards to road users include not only natural objects (such as embankments and trees) and man-made objects (such as utility poles, culvert headwalls and bridge end abutments) but also traffic management devices installed within the roadway – such as traffic signal posts, signposts, lighting columns and safety barriers in gore areas. Detailed guidance on the treatment of these objects is also given in the *Guide to Road Safety Part 8* (Austroads 2015k).

The *Guide to Road Safety Part 5* (Austroads 2006b) provides guidance on safety in rural and remote areas, and summarises aspects of crash risk as a function of driver fatigue. The strategic location of roadside rest areas in the design and management of rural roads can assist in addressing that issue.

The *Guide to Road Design Part 6: Roadside Design, Safety and Barriers* (Austroads 2010) describes a hazard mitigation process that includes the use of the clear zone concept to determine an area of interest – i.e. to define the area beside the road that is of most interest in terms of roadside safety (Section 4.2.2 of the *Guide to Road Design Part 6* (Austroads 2010)). Recent research (Austroads 2011, 2014c, Doecke & Woolley 2011, NZ Transport Agency 2013a) has investigated and quantified the effectiveness of many roadside hazard treatment options.

As outlined in Section 5.2.2, Austroads (2014b) noted that for clear zones, the proportion of casualty run-off-road crashes in which hazards were struck decreased with clear zone width, however the proportion of rollover crashes increased. Austroads (2014b) proposed a roadside safety management framework for the evaluation of roadside hazards and their treatment options, so that FSI can be minimised. These treatments include different clear zone widths used in controlling the likelihood and severity of run-off-road casualty crashes, providing shoulders, making roadside structures more forgiving (e.g. frangible poles), and more effective selection and placement of safety barriers. The proposed framework allows a Safe System evaluation of roadside hazard management options to be carried out at the strategic, route/corridor or localised levels.

5.2.5 Intersections and Crossings

Intersections are points of conflict. Road users need to be aware of their presence (warned), know about the general geometric layout and priorities (informed), ascertain whether they need to turn as appropriate for their journey (guidance) and know when they should proceed (control).

Intersection control may take many forms – signals, signposted priorities, roundabouts – depending on traffic efficiency, safety, and location factors.

While intersections are points of conflict, they are required in a road network unless grade separation is provided. To provide intersections in a Safe System environment, careful consideration needs to be given to the location in relation to the road geometry and in relation to each other. This is so the appropriate layouts and controls for priority are provided.

A poorly located intersection in relation to the road geometry, such as a minor road intersecting a major highway over a crest, can cause sight distance problems for road users. Appropriate intersection sight distances, as discussed in the *Guide to Road Design Part 4* (Austroads 2017d) and its respective sub-parts *Part 4a*, *Part 4b* and *Part 4c* (Austroads 2015i, Austroads 2015n and Austroads 2017c) are required. Signposting the presence of the intersection to warn and inform traffic on the major highway is only partly helpful. A driver on the highway may be alerted to the intersection by suitable warning signs, but may not have enough distance available to avoid a collision if the sight distance is too short.

Intersections located too close to each other can create the problem of one intersection being overlooked by drivers, or drivers being overloaded by too much information (if signalised). Freeway interchanges located too close together can lead to unsafe weaving movements being undertaken between interchanges.

In rural areas, it is important to ensure that road users on highways and main roads are aware of side roads, by relocating them where they can be seen (not over a crest or around the back of a curve), and by providing signs and markings to warn and inform road users of their presence. The safe intersection sight distance for the operating speed of the main road must be provided as a minimum. Road users on the side road need to be aware of the intersection to avoid entering or crossing the major road unexpectedly, the unwanted outcome of which could be a collision with a vehicle on the main road. The approach sight distance must be provided. Where the main road intersection is not immediately obvious, warning signs are required. Hazard marker boards at the back of T-intersections together with direction signs can clearly warn and inform road users of their presence.

Cross-intersections on rural roads with wide medians can create problems. Great care needs to be taken to ensure that the intersection does not look like a roundabout, which can lead to potentially unsafe behaviour by road users on both the main road and side road. Specific wide intersection treatments have been developed in some jurisdictions to avoid the roundabout impression.

Care is required where the usual intersection priority is reversed. Such a case can occur at a T-intersection for example, where traffic on the stem and one leg of the cross-road is given priority. Unless the reversed traffic arrangements are clearly apparent, driver expectancies can lead to increased crash risk. Note that with the Safe System approach larger rural roundabouts are better for controlling speeds than T-junctions.

Treatments for through traffic on highways and main roads need to be considered carefully when providing for right-turns from the major road. Speed differences can be great, leading to a potential for high-speed rear-end or right-angle crashes between through and right-turning vehicles. Possible treatments may include right-turn bays, but their design and location needs to be carefully considered. When the provision for right-turn movements is unavoidable, care should be taken to ensure that this is not provided within or near the commencement of an overtaking lane.

It is noted that the examples in this section are not an exhaustive list of ways to mitigate the potential dangers of intersections. Practitioners should refer to the following Guides for guidance on the appropriate design, layout and traffic management of intersections:

- Guide to Road Design Part 4 (Austroads 2017d) and its respective sub-parts Part 4a, Part 4b and Part 4c (Austroads 2015i, Austroads 2015n and Austroads 2017c)
- Guide to Traffic Management Part 6 (Austroads 2017f).

Suitably designed and managed intersections guide and control drivers through areas of conflict. The use of road safety audits can provide valuable road safety engineering input to the design.

Traffic signals may be used to improve the safety of intersections and crossings. However, as outlined in Austroads (2015h), due to the angle and impact speed of crashes at signalised intersections, traffic signals, especially at higher-speed intersections, are not considered to be fully aligned with the Safe System philosophy. Austroads (2015h) found that the major casualty crash types at signalised intersections involved:

- vehicles undertaking opposing turns
- vehicles travelling in adjacent directions
- vehicles travelling in the same direction (rear-end)
- vehicles colliding with pedestrians.

The key factors associated with these crash types based on a literature review are outlined in Table 5.2.

Austroads (2015h) investigated various approaches to make traditional intersections more aligned with the Safe System philosophy. The report found that the most effective and innovative way to make intersections align is to undertake geometric design changes, with the aim being to reduce crash severity through moderating both impact speeds and angles. These include:

- low-speed signalised roundabouts
- high-speed signalised roundabouts
- horizontal deflections on approaches
- vertical deflections on approaches (e.g. raised intersections) – where no changes to impact angles are intended.

However, due to footprint, cost and operational efficiency, the above solutions may not be viable. As such the report noted that practitioners may look to incorporate a variety of Safe System supporting solutions. These include:

- grade separation
- double diamond cross over
- red-light/speed cameras
- speed limit reductions
- increasing visibility of signal displays (e.g. mast arms)
- movement control and management (ban turns, close approaches and fully control right-turns).

Table 5.2: Summary of factors associated with the occurrence of key crash types at traffic signals

Crash type	International literature (mostly based on casualty crashes)	Severe crash site analysis (probit model factors shown to increase probability of crashes being severe)	In-depth crash analysis (observed site factors present in severe crashes)
Opposing-turning crashes	Lack of right-turn control	All-filter right-turns at the site, when compared to control group of all fully controlled right-turns (FCRT) and mixed right-turn controls*	Partially controlled right-turns (PCRT) or filter right-turn**
	Lack of signal visibility	No mast arms on major road (strong effect) or on minor road (small effect)*	–
	Large sites, wide approaches	–	Multilane approaches, many lanes to filter across
	Red-light running – strong reduction when speed/red-light cameras are introduced	–	Red-light running where FCRT was already present
Adjacent direction crashes	High conflicting traffic movement volumes	Arterial-to-arterial intersection – indicates high volumes	–
	Lack of right-turn control (strong result)	FCRT compared with PCRT and all-filter group (weak result)	–
Adjacent direction crashes (continued)	Lack of signal visibility	–	–
	Red-light running	–	Red-light running (100% of cases)
	Large sites, wide approaches	Arterial to arterial intersection – may indicate larger sites	Large sites, major road approach, high-speed limit
Same direction (rear-end) crashes	High approach traffic volume	Not carried out	Large, multilane sites – possible link
	Improved control of turns		–
	Lack of signal visibility		–
	Presence of red-light cameras		–
	Large intersection size		Large, multilane sites
	High-speed/speed limits		High-speed limit sites
	–		Presence of another traffic signal site nearby (50–200 m)
Pedestrian crashes	Non-residential land use	High pedestrian activity areas	Sites in shopping/commercial areas
	High pedestrian and traffic volumes	High pedestrian activity areas	Sites in shopping/commercial areas
	Large sites	Road hierarchy: arterial with local	Large sites, long waiting time
	Lack of staged crossing	Staged crossing	Majority had staged crossings
	Lack of right-turn control	All-filter right-turns	Partially-controlled or filter turns on vehicle approach
	High-speeds	Speed limits > 60 km/h (weak)	Higher-speed limits, especially in combination with lacking right control
	–	Lack of mast arms on the major road	–

** Based on Melbourne and Brisbane data. ** Based on Melbourne data.*
Note: A probit model is a type of regression model where the outcome can fall only within one of the two categories (e.g. fail or success). The aim of such a model is to estimate factors which affect the probability that an outcome will fall into a specific category (e.g. fail).

Source: Austroads (2015h).

Austroads (2015h) identified that roundabouts are a very effective solution in approaching a Safe System. Their strong safety performance is not extended equally to vehicle and two-wheeler road users, with motorcyclists and cyclists over-represented in the severe crash data. Austroads commissioned an investigation into Bicycle Safety at Roundabouts to identify the geometric factors associated with bicycle crashes at roundabouts. The report (Austroads 2017b) found that the entry path curvature was the main component that needed to be amended to slow entering vehicles. On local roads, with smaller design vehicles, the entry curve radius could be reduced to achieve a speed of ≤ 30 km/h, but on the arterial road roundabouts, reducing the entry speeds was often not feasible due to the larger design vehicles on these roads. The investigation identified several amendments to the Guides including amendments to the *Guide to Road Design Part 4B: Roundabouts* (Austroads 2015i). These suggested amendments may not get incorporated into the Guides immediately and therefore practitioners should refer to Austroads (2017b) and consider the implications of the suggested amendments in work undertaken.

5.2.6 Traffic Controls

In the context of a Safe System, traffic control devices can be used to deliver both safe roads and safe speeds. Safe speeds may be delivered using regulatory (e.g. regulatory speed limit signage) and physical traffic control devices (e.g. local area traffic management devices that reduce the speed of vehicles). Safe roads can be delivered through traffic control devices that control road user movements and behaviour (e.g. traffic signals that control the movement of vehicles) and physical devices that directly influence the passage of vehicles (e.g. medians that control turning movements).

Speed management is fundamental to the safe management of traffic. Guidance on the principles and practice of speed management, with reference to the application of speed limits, is given in the *Guide to Road Safety Part 3* (Austroads 2008a) and the *Guide to Traffic Management Part 5* (Austroads 2017e).

Physical traffic control devices are used to directly inform, guide, and control the movements of road users. To be effective, such traffic controls need to be conspicuous, and their purpose clearly evident.

Threshold treatments, for example, are used to inform drivers of local traffic areas and to control their entry speed into these areas. They need to be clearly evident in the road environment because of their placement and appearance (contrasting colours and materials). In addition, devices such as signs, kerb painting and line marking may be necessary. It is noted that poorly located and inconspicuous thresholds might fail to slow drivers and can become hazards rather than safe controls.

Further examples and guidance on physical traffic controls are given in the *Guide to Traffic Management Part 8* (Austroads 2016c) and the *Guide to Traffic Management Part 10* (Austroads 2016e).

Consistency of treatments along a route is important in obtaining correct road user responses. This can arise in the provision of features such as protected right-turn facilities, successive pedestrian crossing facilities, rural rail crossings, or curve delineation treatments. The principle to be adopted is that the treatment at a location should be commensurate with the risk. This should be overlaid with considerations of consistency along the route, since departure from consistent treatment might be at odds with driver expectancies for that route.

5.2.7 Traffic Signals

As outlined in Austroads (2015j), the primary objective of traffic signals is to provide mobility, safety and access to road users. The contribution of signal management to meeting road user needs from this report is outlined in Table 5.3.

Table 5.3: Contribution of signal management to meeting road user needs

Road user need	Contribution of signal management
Mobility	• Adjust signal timings and phasing to reduce delay at individual intersections, for priority road users/movements at certain times of day. • Improve coordination of signals along a corridor to maximise throughput and progress priority users/movements at certain times of day. • Implement network-wide congestion management strategies (e.g. pre-emption/gating of general traffic) to address recurrent congestion problems in an area. • Support control of access to the network and dissipation of traffic to assist incident management in reducing non-recurrent congestion. • Actively discourage vehicle movements in locations with good level of service for other modes, to encourage modal shift and reduce traffic on the network. • Support public transport and freight movements where intended.
Safety	• Prevent unsafe conflict of movements. • Provide protection to vulnerable road users such as pedestrians and cyclists.
Access	• Improve level of service for all road users. • Assist in improving equity for side/local road access to key arterials during off-peak periods.

Source: Austroads (2015j).

From a safety perspective, the primary role of the traffic signal is to separate, through temporal control, road user movements that are potentially in conflict.

In some cases, signal phase settings may need to be implemented that impact on the intersection capacity. These may need to be implemented to increase the safety of the intersection (e.g. protected turn arrow movements, inter-red phases etc.).

As indicated in Austroads (2015h), traffic signals are not typically identified and promoted as a Safe System solution. This is primarily due to the angle and impact speed of crashes at signalised intersections resulting in a high severity outcome of crashes (e.g. 36% of casualty crashes result in a death or serious injury).

Traffic signals on their own should not be seen as a Safe System solution, and simply installing traffic signals in response to a broadly stated safety problem at an intersection might not address the underlying safety issue. The matter of identifying and implementing appropriate remedial treatments for crash locations is dealt with in detail in the *Guide to Road Safety Part 8* (Austroads 2015k).

The *Guide to Traffic Management Part 6* (Austroads 2017f) provides detailed guidance on the application of traffic signals to intersection control, and the *Guide to Traffic Management Part 10* (Austroads 2016e) presents details of traffic signal facilities and installations. Further advice on signal systems in the traffic operations context is given in the *Guide to Traffic Management Part 9* (Austroads 2016d).

5.2.8 Traffic Signs

Safe System treatments may be split into primary and supporting treatments. Primary treatments focus on reducing the severity of crashes while supporting techniques focus on reducing the number of crashes. At the top of the primary and supporting treatment hierarchy are engineering treatments which aim to provide a safe road through the provision of a safe road alignment, safe cross-section, safe pavement features, safe roadside, safe intersections and crossings etc.

In some cases, it may not be possible to provide a road that is fully compliant with the Safe System principles. To treat the deficiency and work towards a Safe System, there is a need to provide signs to warn and inform road users of the roadway ahead, and to guide and control road users through complex and unusual situations. This is so the road user is not surprised by the element in the roadway and that clear guidance is given. The use of the signs as a supporting mechanism is generally at the bottom of the Safe System treatment hierarchy and they are generally used to encourage motorists to reduce speeds on their approach to a hazard. The effectiveness of signs in preventing fatal and serious injury crashes vary depending on the sign type and application. Austroads (2016f) and Austroads (2014c) provide information on the effectiveness of signs as well as other treatments used to achieve Safe System speeds on urban arterial roads and rural roads respectively.

Standards and guidelines such as the Australian Standard AS 1742: *Manual of Uniform Traffic Control Devices* (set), the New Zealand *Manual of Traffic Signs and Markings* (NZ Transport Agency 2010a) and the New Zealand *Traffic Control Devices Manual* (NZ Transport Agency 2010b) prescribe signing practices – in terms of hierarchy, shape, colour, size, legibility and placement.

It is noted that in New Zealand, requirements like those set out in Australian Standard AS 1742 (set) are contained in *Land Transport Rules: Traffic Control Devices Rule* (2004), *Road User Rule* (2004) and *Speed Limits Rule* (2003).

Departures from common practice can lead to confusion and should be avoided. Poorly located or incorrect signs can lead to a confusing and ambiguous situation, increasing crash risk. Excessive or cluttered signing can present too much information in a short distance, increasing the potential for road user mistakes.

Good road safety engineering should ensure that road signs indicate clearly what is ahead. They must convey the true nature of what lies ahead. This may involve using a combination of standard signs modified to convey the correct message. The standard layout of a warning sign (a black symbolic legend on a yellow background in a diamond shape) should be consistently used; what is modified is the symbolic legend. However, standard signs should not be modified unless necessary, and the use of alternative symbols should be approved only after rigorous testing in accordance with AS 2342-1992.

Where major changes have been made to a road – for example, where a road has been realigned or bypassed and the old road closed – road users must be warned and informed very clearly of these changes, and the messages repeated to reinforce the information being provided.

The *Guide to Traffic Management Part 10* (Austroads 2016e) provides guidance on the appropriate use of signs and markings. The *Guide to Traffic Management Part 8* (Austroads 2016c) also provides similar guidance for local area traffic management schemes.

5.2.9 Markings and Delineation

To provide safe roads there is a need for road markings and delineation to provide information, guidance, and control through lines and symbols (numerical or other characters) for road users. This is to provide clear guidance to the road user and minimise any surprise posed by the road.

While markings and delineation can be driven over, and focus on reducing crashes rather than reducing the severity of the crashes, they are seen more as supporting treatments in the Safe System rather than primary treatments. In that sense, they are like signs. However, markings and delineation are considered higher in the hierarchy of treatments to signs as road markings and delineation are a form of engineering treatment. They work hand-in-hand with the physical construction of new road pavement cross-sections or in some cases are applied to existing cross-sections. Road markings and delineation are critical as they allow road users to determine the way ahead (long-range delineation) and to position the vehicle laterally on the road (short-range delineation). They assist is allowing drivers to use the road in the manner intended and therefore assist in achieving a safe road within a Safe System.

At night, where such guidance is particularly important, reflective devices on or adjacent to the roadway is also used.

Incorrect or poorly maintained pavement markings can lead to incorrect placement or manoeuvres of vehicles, and increase the risk of crashes. Similarly, poorly placed and missing delineation devices can give an inadequate or false picture of the way ahead, and can lead to crashes.

Where alignments are poor, good delineation practice should attempt to indicate not only the way ahead but also the degree or nature of substandard alignment features. For example, at a curve of decreasing radius, chevron alignment markers and additional guide posts could be used to supplement line marking and raised retroreflective pavement markers.

Vehicle run-off-road crashes on rural roads at night might not necessarily involve a failure to detect single objects with which a collision must be avoided, but rather a failure to detect, recognise, and correctly interpret patterns of information from which the position of the vehicle on the roadway and the direction of immediate and subsequent travel can be ascertained. The patterns give information on:

- the path of the road ahead which should allow for easy recognition of the change of road direction, and the severity of curvature so that vehicle speed can be optimised
- the position of the vehicle on the road which should allow for adequate steering control so that proper and safe manoeuvres can be made.

Simple basic delineation can be of great assistance to road users in keeping to their correct side of the road and in determining that oncoming traffic is keeping to its correct side. A centreline can clearly guide drivers through features such as intersections and curves and away from each other.

Post-mounted delineators (guide posts and reflectors) provide long-range guidance on road alignment, allowing drivers to detect any required direction and speed changes. Centrelines and edge-lines, both supplemented by reflective raised pavement markers, provide long-range delineation (particularly on high beam) and short-range delineation, allowing drivers to correctly place their vehicle laterally on the roadway.

On single-lane roads, where line marking cannot be provided, guide posts and reflectors provide both long-range and short-range delineation. The lateral position of the guide posts indicates how far a vehicle can safely move off the single-lane seal to allow an oncoming vehicle to pass. Where a batter slope is present, it is necessary to place the guide posts at the top of the batter slope, even if the batter slope seems shallow. Combined with the slope of the batter, loss of control can occur if a vehicle travels onto the batter slope because of incorrectly placed guide posts on the batter slope.

Maintenance of delineation devices is essential if they are to be effective. Maintenance is not just of the delineation devices themselves, but also the surrounds, particularly vegetation.

The *Guide to Traffic Management Part 10* (Austroads 2016e) provides guidance on the form and placement of pavement line marking and associated delineation devices.

5.2.10 Road Lighting

It is important that road users are not only warned and informed of potential upcoming hazards and conflict points, but the hazard and conflict points are sufficiently visible to the motorist, particularly at night. This enables the driving task to be performed safely by assisting in informing users of the road layout and traffic controls ahead. It is worth noting that road lighting is normally installed on poles, which pose a safety hazard unless they are frangible. Practitioners should consider the benefits of road lighting as outlined in the discussion below in conjunction with the disbenefit of installing a potential roadside hazard. Practitioners should aim to only install lighting on exclusive use poles (i.e. where they are not required for other purposes such as power, or traffic signals) where the benefits of their installation outweigh their disbenefit. This may limit lighting on exclusive poles to the illumination of high-risk areas or the illumination of other road users or locations used by other road users which may not have adequate illumination (e.g. a pedestrian crossing).

While lighting itself cannot ensure traffic safety, it can significantly improve the ability of road users to correctly judge potentially hazardous situations by giving the road user sufficient time to perceive and react to avoid crashes.

Lighting arrangements include route lighting along urban and some semi-rural roadways, assisting delineation of the road ahead, and use of direct illumination of features such as complex intersections, pedestrian crossing facilities or rural intersections and interchanges.

Route lighting design is based on providing a uniformly bright pavement against which objects may be seen in silhouette – dark objects against a light background.

Some road and traffic situations (near crests, tight curves, pedestrian crossings, isolated intersections and road sections with significant pedestrian activity) are not favourable for silhouette vision against the illuminated road pavement, and at such locations, lighting is biased towards direct illumination.

At night visibility is reduced and a human's visual capabilities are impaired. Road lighting, and flood lighting where necessary, can address the situation, but account needs to be taken of peripheral effects such as discomfort glare and disability glare arising from lighting installations, which can adversely affect road user visual performance.

Well-designed road lighting can define the alignment of the road. However, situations can occur where the reverse is the case. For example, lighting on a side road intersecting with a main road on a curve could, from some approach angles, present a misleading impression that the main road alignment continues directly ahead. In such circumstances provision of lighting on the side road should not be considered in isolation but account should also be taken of the view created upstream.

Additional guidance on the design and installation of road lighting, including the accommodation of road user visual needs, is given in the *Guide to Road Design Part 6B* (Austroads 2015a) and the relevant series of Australian Standard AS/NZS 1158 (set).

5.2.11 Roadworks

Safe System principles should not only apply to new and existing roads but should also apply to roads being constructed or where works are being undertaken on the road. As the road is being constructed or worked on, it may often have sub-standard conditions and expose vulnerable road workers and other road users to various traffic scenarios that may not typically represent a Safe System. For this reason, traffic control and management at roadworks is an essential component of network safety management. The immediate environment of roadworks needs to meet the basic safety characteristics of warning, informing, guiding, and controlling approaching road users. In some circumstances, special consideration will need to be given to the safety needs of pedestrians, particularly those who are mobility impaired, in negotiating roadworks. This may include reducing the speed of the vehicles to a safe speed given the presence of pedestrians, including road workers, and/or providing pedestrian protection (e.g. barrier systems).

Traffic management at roadworks aims to ensure the safety of the travelling public and the safety of road construction workers, and is therefore both a traffic safety issue and an occupational health and safety issue. At roadworks with multiple traffic switches, clear driver guidance is required to avoid driver error. Good traffic management is vital to achieving a safe roadworks environment.

Issues needing to be addressed in traffic control arrangements for safety at roadworks include:

- advance warning devices
- obscuration of signs and markings by mud or dust
- clarity of site layouts and paths for through traffic
- speed reduction and control
- conflicts between temporary and previous traffic control features, especially line marking
- barrier types and deployment
- pedestrian and road worker facilities
- dysfunctional site arrangements.

These concerns are magnified at night if there is a low level of reflectorisation on signs and other items, and low levels of delineation of lanes and roadway edges.

A road agency should have a clear strategy and procedures for managing safety at roadworks. The detailed procedures for roadworks safety management should be undertaken in accordance with clearly identified standards and guidelines, and should include requirements for:

- preparation, submission and checking of traffic management plans
- checking of the implementation of traffic management arrangements on-site.

There is an opportunity for the road safety audit process to be used regularly to check the safety of roadworks traffic control arrangements. The *Guide to Road Safety Part 6* (Austroads 2009a) provides a useful overview of safety considerations at roadworks, and includes a set of checklists to guide an assessment of safety.

Requirements for traffic management at roadworks are given in Australian Standard AS 1742.3-2009 and the New Zealand *Code of Practice for Temporary Traffic Management* (NZ Transport Agency 2014).

It is noted that in New Zealand, requirements like those set out in Australian Standard AS 1742 (set) are contained in *Land Transport Rules: Traffic Control Devices Rule* (2004), *Road User Rule* (2004) and *Speed Limits Rule* (2003).

5.2.12 Non-roadwork Incidents

Like roadworks, unplanned incidents (e.g. crashes, road flooding etc.) can result in a temporary (until the incident can be cleared) change to traffic conditions and may result in a partial or full road closure.

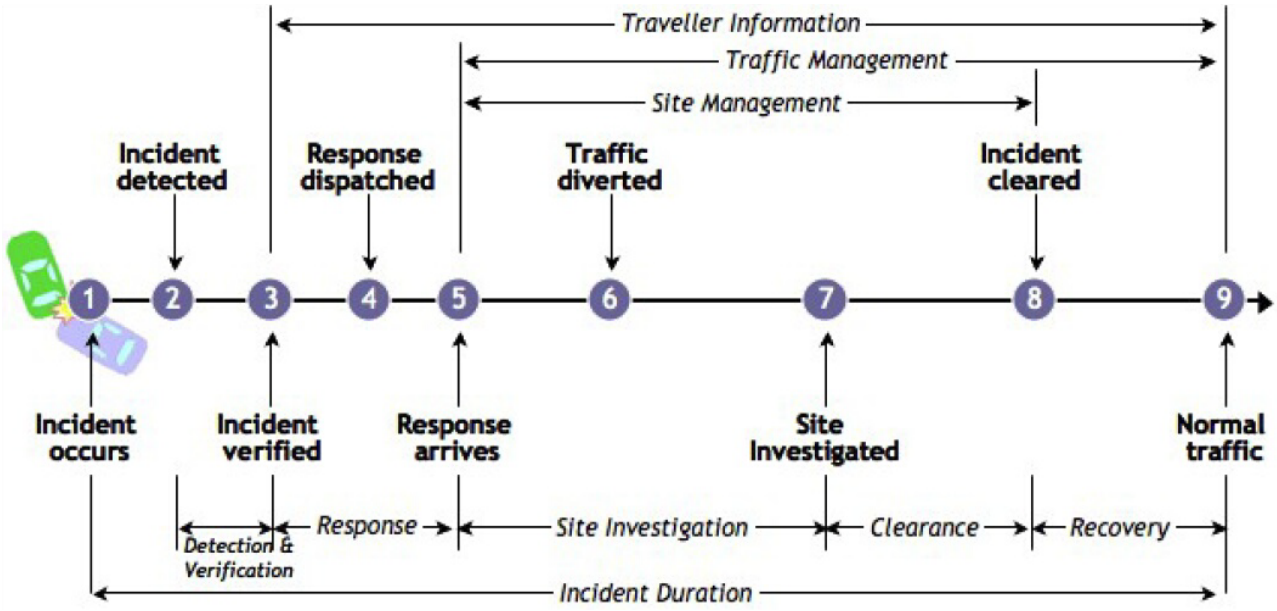
Due to the changed traffic conditions, incidents have not only the potential to disrupt traffic flow and operations but also have the potential to result in secondary incidents that may have safety implications. As a result, incident management is a critical component of maintaining a safe road within a Safe System.

Incident management comprises of:

- detection and verification
- response
- site management
- investigation and clearance
- traffic management
- traveller information.

Figure 5.3 indicates that the total time from when an incident occurs until normal traffic is reinstated is comprised of the time of the individual components. Therefore, there is a need to plan for incident management so that responders are prepared and can implement procedures to best maintain a safe road environment, even though traffic conditions have changed.

Figure 5.3: Timeline of traffic incident management



Source: Austroads (2016d).

A timely response to incidents is important because it:

- reduces total incident duration
- saves lives by expediting ambulance services and reduces the long-term impact of injury
- reduces the probability of secondary incidents.

The *Guide to Traffic Management Part 9: Traffic Operations* (Austroads 2016d) provides detailed guidance on incident management that will contribute to maintaining a safe road environment during the timeframe of the incident. These include:

- planning for traffic incident management
- incident detection and verification
- responses to traffic incidents
- traffic incident site management, investigation and clearance
- traffic management and traveller information.

While incident management comprises of some key unique steps, including those outlined directly above, the management of traffic where an incident occurs is a combination of the general principles for roadworks as outlined in AS 1742.3-2009, and the use of standard traffic control and communication devices outlined in the *Guide to Traffic Management Part 10: Traffic Control and Communication Devices* (Austroads 2016e).

5.2.13 On-road Public Transport

On-road public transport in Australia and New Zealand generally comprises of buses and light rail (i.e. trams). Buses and light rail either share the road space with other road users or provide public transport services through using segregated road space. In addition, Australian and New Zealand roads interact with the heavy rail (trains) through level crossings and railway stations located near the roads.

Where there is on-road public transport or public transport that interacts with the road, through sharing road space, providing for pedestrian access, or through light and heavy rail crossings, there is a need to manage the interactions between the various road users. The ways various road users interact with on-road public transport and the public transport that interacts with the road present various safety issues. The main issue is how vulnerable road users interact with public transport.

The *Guide to Traffic Management Part 7: Traffic Management in Activity Centres* (Austroads 2015b) provides guidance on public transport access and operation, on-road public transport in the traffic system, quality of passenger access to public transport and signs and information. Austroads (2015b) also provides reference to other parts of the *Guide to Traffic Management* and the *Guide to Road Design* including references to the following:

- public transport networks and considerations for network operation planning (the *Guide to Traffic Management Part 4* (Austroads 2016b))
- public transport planning (the *Guide to Traffic Management Part 4* and *Part 11* (Austroads 2016b, 2017a) and *Guide to Road Transport Planning* (Austroads 2009e))
- issues in managing on-road public transport at the mid-block (the *Guide to Traffic Management Part 5* (Austroads 2017e))
- managing road space allocation at the mid-block (the *Guide to Traffic Management Part 5* (Austroads 2017e))
- traffic management issues and requirements at intersections (the *Guide to Traffic Management Part 6* (Austroads 2017f))
- providing for buses in local area traffic management (the *Guide to Traffic Management Part 8* (Austroads 2016c))
- traffic control devices and traffic operations to support on-road public transport (the *Guide to Traffic Management Part 9 and Part 10* (Austroads 2016d, 2016e))
- parking at public transport nodes and park-n-ride facilities (the *Guide to Traffic Management Part 11* (Austroads 2017a))
- design of bus stops and bus lanes (the *Guide to Road Design Part 3* (Austroads 2016g))
- design of public transport facilities at intersections (*Guide to Road Design Part 4* (Austroads 2017d) and its respective sub-parts *Part 4a*, *Part 4b* and *Part 4c* (Austroads 2015i, Austroads 2015n and Austroads 2017c)).

Practitioners should refer to the *Guide to Traffic Management Part 7* (Austroads 2015b) for guidance on public transport access and operation and other parts of the *Guide to Traffic Management* and the *Guide to Road Design* for other guidance on public transport in relation to the road environment. In addition, to ensure the Safe System principles, apply to the interfaces on public transport, road practitioners should implement network operation planning. This ensures the road is designed and operated to suit its function and that the Safe System Assessment Framework is applied as outlined in Section 4.4.

Traffic control of at-grade level crossings may be catered for using either passive or active controls. Passive control is primarily catered for using signage and line markings to indicate the presence of trains to the user. Active control is catered for using devices such as flashing lights, gates and barriers to indicate the presence of a train to the user and to physically control access to the at-grade level crossing during the time when the train is within range of or passing through the level crossing. Both methods increase safety of at-grade level crossings, although the active control provides a higher level of safety than passive control measures. For further information on safety at rail crossings refer to the *Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings* (Austroads 2017f).

5.2.14 Vehicle Safety

As described in Section 2, safe vehicles are one of the four key pillars of a Safe System. Safe vehicles can aid in achieving a Safe System through using in-vehicle technologies that not only aid in avoiding crashes but can reduce the consequence when a crash occurs. Safe vehicles play a key role in reducing FSI.

Current and emerging technologies used to avoid crashes can now be classified into the SAE automated driving levels as described in Section 3 with C-ITS also emerging. The technologies used to reduce the injury consequences of a crash to the vehicle occupants are assessed for safety through the Australasian New Car Assessment Program (ANCAP).

ANCAP ratings are achieved through crash testing of the vehicle in various situations and speeds, with the rating based on how well the vehicle could protect the occupant of the vehicle from death or serious injury. The higher the ANCAP rating the safer the vehicle, for the period of testing (i.e. the standard to achieve a five-standard rating evolves with time as vehicle safety standards evolve). ANCAP (2017) provides further information on the ratings.

5.3 Engineering Treatments to Address Specific Crashes at Specific Locations

In addition to the guidance outlined in Section 5.2, Appendix F of the *Guide to Road Safety Part 8: Treatment of Crash Locations* (Austroads 2015k) outlines the likely expected crash reductions, because of engineering treatments. These are referred to as crash reduction factors (CRFs) and are applied to various countermeasures for common types of intersection and non-intersection crashes.

The CRFs provide an indication of the expected percentage reduction (or increase) compared with the existing crash rate following the implementation of a countermeasure. This helps the practitioner choose the treatments that are likely to bring about the greatest safety benefits depending on the crash types targeted.

The crash modification factor (CMF) serves as a simple multiplication factor applied to the existing crash rate. Therefore, a CMF of less than one indicates a reduction in the crash rate, whilst a CMF greater than one indicates an increase.

The CRF and CMF provide the expected percentage reduction or increase in casualty crashes (i.e. a CMF of 0.8 would be the same as a CRF of 20%). Care should be taken when using CRF as it has the potential to confuse the practitioner as to whether the crash rate has increased or decreased by the designated percentage.

There is a good knowledge base on all casualty crashes, however far less is known about the influence on fatal and serious outcomes.

In addition to the guidance outlined in the *Guide to Road Safety Part 8* (Austroads 2015k), further information relevant to Australia and New Zealand can also be found in Austroads (2012b) and the Austroads Road Safety Engineering Toolkit. The NZ Transport Agency (2016) presents methods for estimating the predicted injury rates for various road environments in New Zealand, of which a portion of the CMF and CRF values were developed or gathered as part of research by Austroads. In addition, individual road agencies may have their own expanded lists of countermeasures.

The effectiveness of the countermeasures is dependent on the correct identification of the cause of crashes at the specific location. The process must firstly identify whether the safety problem at a location is amenable to treatment, then determine what (if anything) that treatment should be. The countermeasure for one crash problem is likely to be different from the countermeasure for another problem and in some cases the countermeasures may possibly even be in conflict. In such cases road safety engineering knowledge and judgement is required to assess all possible positive and negative effects, including possible further countermeasures to address the negative effects.

References

ANCAP 2017, *ANCAP*, website*,* ANCAP, Canberra, ACT, viewed 17 February 2017, <https://www.ancap.com.au>.

ARRB Group 2014, *Australian National Risk Assessment Model (ANRAM),* webpage, ARRB Group, Vermont South, Vic, viewed 17 February 2017, <https://www.arrb.com.au/Safe-Systems-Parking/Assessing-Managing-Road-Crash-risk/Australian-National-Risk-Assessment-Model.aspx>.

Australian Transport Council 2011, *National road safety strategy 2011–2020*, ATC, Canberra, ACT.

Austroads 2003, *Self-regulation of older drivers: a review*, AP-R221-03, Austroads, Sydney, NSW.

Austroads 2006a, *Guide to road safety part 7: road network crash risk assessment and management,* AGRS07-06, Austroads, Sydney, NSW.

Austroads 2006b, *Guide to road safety part 5: road safety for rural and remote areas*, AGRS05-06, Austroads, Sydney, NSW.

Austroads 2008a, *Guide to road safety part 3: speed limits and speed management*, AGRS03-08, Austroads, Sydney, NSW.

Austroads 2008b, *Guide to road safety part 9: roadside hazard management*, AGRS09-08, Austroads, Sydney, NSW.

Austroads 2009a*, Guide to road safety part 6: road safety audit,* 3rd edn, AGRS06-09, Austroads, Sydney, NSW.

Austroads 2009b, *Guide to asset management part 5: pavement performance,* AGAM05-09, Austroads, Sydney, NSW.

Austroads 2009e, *Guide to road transport planning*, AGRTP-09, Austroads, Sydney, NSW.

Austroads 2009f, *Guide to asset management part 5f: skid resistance,* AGAM05F-09, Austroads, Sydney, NSW.

Austroads 2009g, *Guide to asset management part 5g: texture,* AGAM05G-09, Austroads, Sydney, NSW.

Austroads 2009h, *Guide to pavement technology part 7: pavement maintenance,* AGPT07-09, Austroads, Sydney, NSW.

Austroads 2010, *Guide to road design part 6: roadside design, safety and barriers*, 2nd edn, AGRD06-10, Austroads, Sydney, NSW.

Austroads 2011, *Improving roadside safety stage 2: interim report*, AP-R387-11, Austroads, Sydney, NSW.

Austroads 2012a, *Cooperative ITS strategic plan*, AP-R413-12, Austroads, Sydney, NSW.

Austroads 2012b, *Effectiveness of road safety engineering treatments*, AP-R422-12, Austroads, Sydney, NSW.

Austroads 2013a, *Guide to road safety part 1: road safety overview*, 3rd edn, AGRS01-13, Austroads, Sydney, NSW.

Austroads 2013b, *Guide to road safety part 2: road safety strategy and evaluation*, 2nd edn, AGRS02-13, Austroads, Sydney, NSW.

Austroads 2013d, *Impact of roadside advertising on road safety*, AP-R420-13, Austroads, Sydney, NSW.

Austroads 2014b, *Improving roadside safety: summary report*, AP-R437-14, Austroads, Sydney, NSW.

Austroads 2014c, *Methods for reducing speeds on rural roads: compendium of good practice*, AP-R499-14, Austroads, Sydney, NSW.

Austroads 2015a, *Guide to road design part 6B: roadside environment*, AGRD06B-15, Austroads, Sydney, NSW.

Austroads 2015b, *Guide to traffic management part 7: traffic management in activity centres*, 2nd edn, AGTM07-15, Austroads, Sydney, NSW.

Austroads 2015c, *Road geometry study for improved rural safety*, AP-T295-15, Austroads, Sydney, NSW.

Austroads 2015d, *Safe system in the planning process*, AP-R488-15, Austroads, Sydney, NSW.

Austroads 2015e, *Review of the national road safety strategy*, AP-R477-15, Austroads, Sydney, NSW.

Austroads 2015f, *Road fatalities and serious injuries in Australia and New Zealand 2001-10*, AP-R478-15, Austroads, Sydney, NSW.

Austroads 2015g, *Concept of operations for C-ITS core functions*, AP-R479-15, Austroads, Sydney, NSW.

Austroads 2015h, *Improving the performance of safe system infrastructure: final report*, AP-R498-15, Austroads, Sydney, NSW.

Austroads 2015i, *Guide to road design part 4B: roundabouts*, AGRD04B-15, Austroads, Sydney, NSW.

Austroads 2015j, *Signal management techniques to support network operations*, AP-R494-15, Austroads, Sydney, NSW.

Austroads 2015k, *Guide to road safety part 8: treatment of crash locations*, 2nd edn, AGRS08-15, Austroads, Sydney, NSW.

Austroads 2015l, *Guide to road design part 1: introduction to road design*, 4th edn, AGRD01-15, Austroads, Sydney, NSW.

Austroads 2015m, *Summary of literature of the effective components of graduated driver licensing systems*, AP-R476-15, Austroads, Sydney, NSW.

Austroads 2015n, *Guide to road design part 4C: interchanges*, AGRD04C-15, Austroads, Sydney, NSW.

Austroads 2016a, *Safe system assessment framework*, AP-R509-16, Austroads, Sydney, NSW.

Austroads 2016b, *Guide to traffic management part 4: network management*, 4th edn, AGTM04-16, Austroads, Sydney, NSW.

Austroads 2016c, *Guide to traffic management part 8: local area traffic management*, 2nd edn, AGTM08-16, Austroads, Sydney, NSW.

Austroads 2016d, *Guide to traffic management part 9: traffic operations*, 3rd edn, AGTM09-16, Austroads, Sydney, NSW.

Austroads 2016e, *Guide to traffic management part 10: traffic control and communication devices*, AGTM10-16, Austroads, Sydney, NSW.

Austroads 2016f, *Achieving Safe System speeds on urban arterial roads: compendium of good practice*, AP-R514-16, Austroads, Sydney, NSW.

Austroads 2016g, *Guide to road design part 3: geometric design*, 3rd edn, AGRD03-16, Austroads, Sydney, NSW.

Austroads 2016h, *Guide to traffic management part 12: traffic impacts of developments*, 2nd edn, AGTM12-16, Austroads, Sydney, NSW.

Austroads 2016i, *Guide to smart motorways*, AGSM-16, Austroads, Sydney, NSW.

Austroads 2017a, *Guide to traffic management part 11: parking*, 2nd edn, AGTM11-17, Austroads, Sydney, NSW.

Austroads 2017b, *Bicycle safety at roundabouts*, AP-R542-17, Austroads, Sydney, NSW.

Austroads 2017c, *Guide to road design part 4A: unsignalised and signalised intersections*, AGRD04A-17, Austroads, Sydney, NSW.

Austroads 2017d, *Guide to road design part 4: intersections and crossing: general*, AGRD04-17, Austroads, Sydney, NSW.

Austroads 2017e, *Guide to traffic management part 5: road management*, 3rd edn, AGTM05-17, Austroads, Sydney, NSW.

Austroads 2017f, *Guide to traffic management part 6: intersections, interchanges and crossings*, 3rd edn, AGTM06-17, Austroads, Sydney, NSW.

Brindle, RE 2001, 'Planning and road safety: opportunities and barriers'*, Australasian Transport Research Forum (ATRF), 24th, 2001, Hobart, Tasmania, Australia*, Department of Infrastructure, Energy and Resources, Hobart, Tas, 23 pp.

Department of Infrastructure and Regional Development 2015, *National road safety action plan 2015-2017*, DIRD, viewed 15 February 2017, <http://roadsafety.gov.au/action-plan/>.

Department of Infrastructure and Regional Development 2016, *The safe system approach*, DIRD, viewed 15 February 2017, <http://roadsafety.gov.au/nrss/safe-system.aspx>.

Dewar, R & Olsen, P 2007, *Human factors in traffic safety*, 2nd edn, Lawyers & Judges Publishing Company, Tucson, Arizona, USA.

Doecke, S & Woolley, J 2011, *Cost benefit analysis of intelligent speed adaptation*, CASR093, Centre for Automotive Safety Research, University of Adelaide, Adelaide, SA.

DPTI 2014, *Advertising signs assessment guidelines for road safety*, report 7493298, DPTI, Adelaide, SA.

Elvik, R, Høye, A, Vaa, T & Sørensen, M 2009, *The handbook of road safety measures*, 2nd edn*,* Emerald, Bingley, UK.

ERTRAC 2015, *Automated driving roadmap*, ERTRAC, viewed 16 February 2017, <http://www.ertrac.org/uploads/documentsearch/id38/ERTRAC_Automated-Driving-2015.pdf>.

Grandjean, E 1988, *Fitting the task to the man: a textbook of occupational ergonomics*, 4th edn, Taylor & Francis, London, UK.

Haddon, W 1980, 'Advances in the epidemiology of injuries as a basis for public policy', *Public Health Reports*, vol. 95, no. 5, pp. 411-21.

Homburger, WS & Kell, JH 1989, *Fundamentals of traffic engineering*, 12th edn, Institute of Transportation Studies, University of California, Berkeley, CA, USA.

Ministry of Transport 2014, *Strategy 2010–2020: the safer journeys strategy*, Ministry of Transport, Wellington, New Zealand, viewed 19 June 2015, <http://www.saferjourneys.govt.nz/about-safer-journeys/strategy-2010-2020/>.

NZ Transport Agency 2005, *Guidelines for developing and implementing a safety management system for road controlling authorities*, NZTA, Wellington, New Zealand, viewed 19 June 2015, <http://www.nzta.govt.nz/resources/sms/guidelines-developing/index.html>.

NZ Transport Agency 2010a, *Manual of traffic signs and markings (MOTSAM): parts 1 and 2*, NZTA, Wellington, New Zealand.

NZ Transport Agency 2010b, *Traffic control devices manual (TCD manual): part 1: general requirements for traffic signs*, NZTA, Wellington, New Zealand, viewed 19 June 2015, <http://www.nzta.govt.nz/resources/traffic-control-devices-manual/references.html>.

NZ Transport Agency 2013a, *Use of roadside barriers versus clear zones*, RR 517, NZTA, Wellington, New Zealand.

NZ Transport Agency 2013b, *Road safety audit procedures for projects: guidelines*, NZTA, New Zealand, viewed 23 February 2017, <https://www.nzta.govt.nz/assets/resources/road-safety-audit-procedures/docs/road-safety-audit-procedures-tfm9.pdf>.

NZ Transport Agency 2013c, *NZTA T10 Specification: 2013: Specification for state highway skid resistance management*, NZTA, New Zealand, viewed 23 February 2017, <http://www.nzta.govt.nz/assets/resources/skid-resistance-investigation-treatment-selection/docs/T10-skid-resistance-investigation-treatment-selection-201306.pdf>.

NZ Transport Agency 2014, *Code of practice for temporary traffic management (CoPTTM): part 8 of the traffic control devices manual (TCD manual)*, 4th edn, NZTA, Wellington, New Zealand.

NZ Transport Agency 2016, *Crash estimation compendium (New Zealand crash risk factors guidline)*, 1st edn, NZTA, New Zealand.

Ogden, KW 1996, *Safer roads: a guide to road safety engineering*, Avebury Technical, Aldershot, UK.

Olsen, P 2010, *Forensic aspects of driver perception and response*, 3rd edn, Lawyers and Judges Publishing Company, Tucson, Arizona, USA.

PIARC 2015, 'Design for road user characteristics and compliance', in *Road safety manual: a manual for practitioners and decision makers on implementing safe system infrastructure*, 2nd edn, World Road Association (PIARC), viewed 16 February 2017, <http://roadsafety.piarc.org/en/planning-design-operation/designing-road-users>.

Roads and Traffic Authority 2006, *Road environment safety: a practitioner's reference guide to safer roads*, RTA/Pub.05.323, RTA, Sydney, NSW.

Sanders, MS & McCormick, EJ 1993, *Human factors in engineering and design*, 7th edn, McGraw Hill, New York, USA.

Viner, D & English, N 1995, *Risk engineering models in road safety*, report CR 1/95, Roads and Traffic Authority, Rosebery, NSW.

Wundersitz, LN, Baldock, MRJ & Raftery, SJ 2015, *The relative contribution of system failures and extreme behaviour in South Australian fatal crashes, 2008-2009*, report CASR111, Centre for Automotive Safety Research, Adelaide, SA.

Standards Australia

AS 1742 Set-2014, *Manual of uniform traffic control devices*.

AS 1742.1-2014, *Manual of uniform traffic control devices: part 1: general introduction and index of signs*.

AS 1742.2-2009, *Manual of uniform traffic control devices: part 2: traffic control devices for general use*.

AS 1742.3-2009, *Manual of uniform traffic control devices: part 3: traffic control for works on roads*.

AS 1742.4-2008, *Manual of uniform traffic control devices: part 4: speed controls*.

AS 1742.5-1997, *Manual of uniform traffic control devices: part 5: street name and community facility name signs*.

AS 1742.6-2014, *Manual of uniform traffic control devices: part 6: tourist and services signs*.

AS 1742.7-2016, *Manual of uniform traffic control devices: part 7: railway crossings*.

AS 1742.9-2000, *Manual of uniform traffic control devices: part 9: bicycle facilities*.

AS 1742.10-2009, *Manual of uniform traffic control devices: part 10: pedestrian control and protection*.

AS 1742.11-2016, *Manual of uniform traffic control devices: part 11: parking controls*.

AS 1742.12-2000, *Manual of uniform traffic control devices: part 12: bus, transit, tram and truck lanes*.

AS 1742.13-2009, *Manual of uniform traffic control devices: part 13: local area traffic management*.

AS 1742.14-2014, *Manual of uniform traffic control devices: part 14: traffic signals*.

AS 1742.15-2007, *Manual of uniform traffic control devices: part 15: direction signs, information signs and route numbering*.

AS 2342-1992, *Development, testing and implementation of information and safety symbols and symbolic signs*.

AS/NZS 1158 Set-2010, *Lighting for roads and public spaces*.

SAE International

SAE J3016:2016, *Taxonomy and definitions for terms relating to driving automation systems for on-road motor vehicles*.

Appendix A Safe Road Environment Elements – Standards and Guidelines Directory

The cornerstones of the Safe System approach are to ensure that there are safe roads, safe speeds, safe vehicles and safe people. This is achieved through safety in planning, design, construction, operation, maintenance and use. The tables outlined in this Appendix provide linkages to various parts of the *Guide to Traffic Management*, the *Guide to Road Design* and the *Guide to Road Safety* series, AS 1742 (set), *Road Safety Audit Procedures for Projects* (NZ Transport Agency 2013b) along with the *T10 Specification* (NZ Transport Agency 2013c). These documents provide guidance on how to achieve safety using safe road environment features for various road environment elements.

A safe road environment can be defined as one which provides for all road users the features listed below:

- **Warn** road users of any approaching substandard, unusual or complex features in the road environment that pose an unexpected elevated risk.
- **Inform** road users of the way ahead, and of the type of unusual conditions likely to be encountered.
- **Guide** road users along sections of a route and through unusual sections of a route.
- **Control** road users at conflict points or areas of conflict, and manage their speed.
- **Forgive** errant road users and inappropriate behaviour or mistakes, with the severity of consequences being minimised.
- **Contain no surprises** to the road user, where reliable and consistent responses and performance may be expected.
- **Provide a controlled release of information** through avoidance of road user information overload.
- **Repeat information where necessary** to ensure that crucial information is unlikely to be missed, overlooked or forgotten by road users.
- **Provide information in a consistent manner** to meet the expectations of the road user by ensuring similar situations are treated in a similar manner, based on their expectations built up from previous experiences.
- **Provide adequate surface friction** through reasonable and predictable surface friction requirements, and facilitate recovery from emergencies.
- **Provide opportunities for rest and recuperation** for road users to avoid the effects of fatigue, particularly on longer trips on rural highways.

Linkage to the parts for the various guides are summarised in Table A 1 and outlined in the tables contained in this Appendix as follows:

- Road geometry: Table A 2
- Pavement: Table A 3
- Roadside: Table A 4
- Intersections: Table A 5
- Traffic controls: Table A 6
- Signs: Table A 7
- Markings: Table A 8
- Lighting: Table A 9.

Speed management, as discussed in Section 4.4.3, is not identified as a safe road environment feature. However, as speed management comprises the controlling of the speed it is primarily catered for through the various road environment elements but through traffic controls, signs and markings.

Table A 1: Safe road environment elements – standards and guidelines directory

Safe road environment features	Road environment elements							
	Road geometry	Pavement	Roadside	Intersections	Traffic controls	Signs	Markings	Lighting
Warn						AS 1742 Parts 1, 2, 3, 10 GTM Part 8	AS 1742.13	
Inform	GRD Parts 1, 3			GRD Parts 1, 4, 4A, 4B, 4C		AS 1742 Parts 1, 15 GTM Parts 8, 10	AS 1742.13 GTM Parts 8, 10	AS/NZS 1158 GRD Part 6B
Guide				GRD Parts 4, 4A, 4B, 4C GTM Parts 6, 8	AS 1742.3 GTM Parts 5, 8, 9, 10	AS 1742 Parts 1, 5, 6, 7, 9, 15 GTM Parts 8, 10	AS 1742 Parts 2, 7, 9, 14 GTM Parts 8, 10	AS/NZS 1158 GRD Part 6B
Control			AS 1742.11 GTM Part 11	GTM Part 8	AS 1742 Parts 3, 7, 10, 13, 14 GTM Parts 5, 8, 9, 10 GRS Part 3	AS 1742 Parts 1, 2, 3, 4, 7, 10, 12, 13, 14 GTM Parts 8, 10	AS 1742 Parts 4, 7, 10, 12, 13 GTM Parts 8, 10	
Forgive	GRD Part 6 GRS Parts 6, 8 NZTA RSA	GRS Parts 6, 8 NZTA RSA	GRD Part 6 GRS Parts 6, 8, 9 NZTA RSA	GRS Parts 6, 8 NZTA RSA	GRS Parts 6, 8 NZTA RSA		GRS Part 8	
No surprise	GRD Parts 1, 3 GRS Part 6 NZTA RSA	GRS 6 NZTA RSA	GRS Part 6 NZTA RSA	GRD Part 4 GTM Part 6 GRS Part 6 NZTA RSA	GRS Part 6 NZTA RSA	GRS Part 6 NZTA RSA	GRS Part 6 NZTA RSA	AS/NZS 1158
Controlled release		GRD Part 4		GRS Part 6 NZTA RSA	AS 1742.2 GTM Parts 5, 8, 9, 10 GRS Part 6 NZTA RSA	AS 1742.13 GTM Parts 8, 10 GRS Part 6 NZTA RSA	AS 1742.13 GTM Parts 8, 10 GRS Part 6 NZTA RSA	
Repeat information					AS 1742.2 GTM Parts 5, 8, 9, 10 GRS Part 3	AS 1742.13 GTM Parts 8, 10	AS 1742.13 GTM Parts 8, 10	
Meet expectations	GRD Parts 1, 3	GRD Part 4			AS 1742.2 GTM Parts 5, 8, 9, 10 GRS Part 3	AS 1742.13 GTM Parts 8, 10	AS 1742.13 GTM Parts 8, 10	

Safe road environment features	Road environment elements							
	Road geometry	Pavement	Roadside	Intersections	Traffic controls	Signs	Markings	Lighting
Friction supply		GAM Parts 5F, 5G GPT Part 7 NZTA T10	GAM Parts 5F, 5G GPT Part 7 NZTA T10					
Rest and recuperation			GRS Part 5			GRS Part 5		

Key:
GTM: Guide to Traffic Management
GRS: Guide to Road Safety
GRD: Guide to Road Design
GAM: Guide to Asset Management
GPT: Guide to Pavement Technology
AS 1742: Australian Standard: Manual of uniform traffic control devices
AS/NZS 1158: Australian Standard: Lighting for roads and public spaces
NZTA T10: New Zealand Transport Agency Specification T10
NZTA RSA: Road safety audit procedures for projects

Table A 2: Road geometry

Safe road environment features	**Road environment element**
	Road geometry (horizontal and vertical alignment)
Warn road users of any approaching substandard, unusual or complex features in the road environment that pose an unexpected elevated risk	
Inform road users of the way ahead, and of the type of unusual conditions likely to be encountered	• GRD Part 1 Introduction to road design - Outlines the road design philosophy and principles, why there should be consistency in design and how to address these areas • GRD Part 3 Geometric design - Guides the designer on the sight distance parameters to ensure that the driver is informed of unusual conditions
Guide road users along sections of a route and through unusual sections of a route	
Control road users at conflict points or areas of conflict, and manage their speed	

Safe road environment features	Road environment element
	Road geometry (horizontal and vertical alignment)
Forgive errant road user inappropriate behaviour or mistakes, with the severity of consequences being minimised	• GRD Part 6 Roadside design, safety and barriers - Provides guidance on roadside design, safety and barriers to provide a forgiving roadside, taking into consideration elements such as road geometry • GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the forgiving nature of the roadside based on the road geometry • GRS Part 8 Treatment of crash locations - Outlines the diagnosis and treatment of locations, taking into consideration factors such as road geometry • NZTA RSA - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the forgiving nature of the roadside based on the road geometry
No surprise to the road user, where reliable and consistent responses and performance may be expected	▪ GRD Part 1 Introduction to road design - Outlines the road design philosophy and principles, why there should be consistency in design and how to address these areas ▪ GRD Part 3 Geometric design - Guides the designer on speed parameters, cross-section, sight distance, vertical and horizontal alignment and auxiliary lanes with the intention of having reliable and consistent roads ▪ GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the consistencies in the road design • NZTA RSA - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the consistencies in the road design
Controlled release through avoidance of road user information overload	
Repeat information to ensure that crucial information is unlikely to be missed, overlooked or forgotten by road users	
Meet expectations of the road user by ensuring similar situations are treated in a similar manner, based on their expectations built up from previous experiences	• GRD Part 1 Introduction to road design - Outlines the road design philosophy and principles, why there should be consistency in design and how to address these areas • GRD Part 3 Geometric design - Guides the designer on speed parameters, cross-section, sight distance, vertical and horizontal alignment and auxiliary lanes with the intention of having reliable and consistent roads
Friction supply through reasonable and predictable surface friction requirements, and facilitate recovery from emergencies	
Rest and recuperation areas for road users to avoid the effects of fatigue, particularly on longer trips on rural highways	

Table A 3: Pavement

Safe road environment features	Road environment element Pavement (friction, roughness, rutting) Cross-section (lane widths, formation width, crossfall, superelevation)
Warn road users of any approaching substandard, unusual or complex features in the road environment that pose an unexpected elevated risk	
Inform road users of the way ahead, and of the type of unusual conditions likely to be encountered	
Guide road users along sections of a route and through unusual sections of a route	
Control road users at conflict points or areas of conflict, and manage their speed	
Forgive errant road user inappropriate behaviour or mistakes, with the severity of consequences being minimised	• GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the pavement • GRS Part 8 Treatment of crash locations - Outlines the diagnosis and treatment of locations, taking into consideration factors such as pavement surface • NZTA RSA - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the pavement
No surprise to the road user, where reliable and consistent responses and performance may be expected	• GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the consistencies in the road design • NZTA RSA - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the consistencies in the road design
Controlled release through avoidance of road user information overload	• GRD Part 4 Intersections and crossings: general - Gives guidance for the design of cross-sections to enable controlled movement of vehicles, public transport, pedestrians and cyclists
Repeat information to ensure that crucial information is unlikely to be missed, overlooked or forgotten by road users	
Meet expectations of the road user by ensuring similar situations are treated in a similar manner, based on their expectations built up from previous experiences	• GRD Part 4 Intersections and crossings: general - Gives guidance on the design of cross-sections to ensure that they meet the expectations, based on previous experience, for vehicles, public transport, pedestrians and cyclists

Safe road environment features	Road environment element Pavement (friction, roughness, rutting) Cross-section (lane widths, formation width, crossfall, superelevation)
Friction supply through reasonable and predictable surface friction requirements, and facilitate recovery from emergencies	• GAM Part 5F Skid resistance - Gives guidance on testing the skid resistance for pavement and decision support tools to ensure there is adequate friction supply • GAM Part 5G Texture - Gives guidance on testing the texture for pavement and decision support tools to ensure there is adequate friction supply • GPT Part 7 Pavement maintenance - Gives guidance on checking condition and maintenance measures to ensure that the pavement can supply required friction • NZTA T10 - Gives guidance on testing the skid resistance for pavement and decision support tools to ensure there is adequate friction supply
Rest and recuperation areas for road users to avoid the effects of fatigue, particularly on longer trips on rural highways	

Table A 4: Roadside

Safe road environment features	Road environment element Roadside (terrain, watercourses, trees, cuttings, embankments, culverts, drainage pits, poles, barriers, pathways, cycleways)
Warn road users of any approaching substandard, unusual or complex features in the road environment that pose an unexpected elevated risk	
Inform road users of the way ahead, and of the type of unusual conditions likely to be encountered	
Guide road users along sections of a route and through unusual sections of a route	
Control road users at conflict points or areas of conflict, and manage their speed	• AS 1742.11 Parking controls - Gives guidelines about road design for conflict points caused by parking • GTM Part 11 Parking - Guides road designs for conflict points caused by parking

Safe road environment features	Road environment element Roadside (terrain, watercourses, trees, cuttings, embankments, culverts, drainage pits, poles, barriers, pathways, cycleways)
Forgive errant road user inappropriate behaviour or mistakes, with the severity of consequences being minimised	• GRD Part 6 Roadside design, safety and barriers - Provides guidance on roadside design, safety and barriers to provide a forgiving roadside • GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the forgiving nature of the roadside • GRS Part 8 Treatment of crash locations - Outlines the diagnosis and treatment of locations, taking into consideration factors such as the roadside and whether it is forgiving • GRS Part 9 Roadside hazard management - Outlines the hazards of run-off-road crashes and the need to assist in minimising the risk by providing a forgiving roadside • NZTA RSA - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the forgiving nature of the roadside
No surprise to the road user, where reliable and consistent responses and performance may be expected	• GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the consistencies in the road design with measures such as safety barriers • NZTA RSA – Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the consistencies in the road design with measures such as safety barriers
Controlled release through avoidance of road user information overload	
Repeat information to ensure that crucial information is unlikely to be missed, overlooked or forgotten by road users	
Meet expectations of the road user by ensuring similar situations are treated in a similar manner, based on their expectations built up from previous experiences	
Friction supply through reasonable and predictable surface friction requirements, and facilitate recovery from emergencies	• GAM Part 5F Skid resistance - Gives guidance on testing the skid resistance for paved shoulders and decision support tools to ensure there is adequate friction supply • GAM Part 5G Texture - Gives guidance on testing the texture for paved shoulders and decision support tools to ensure there is adequate friction supply • GPT Part 7 Pavement maintenance - Gives guidance on checking condition and maintenance measures to ensure that paved shoulders can supply required friction • NZTA T10 - Gives guidance on testing the skid resistance for paved shoulders and decision support tools to ensure there is adequate friction supply
Rest and recuperation areas for road users to avoid the effects of fatigue, particularly on longer trips on rural highways	• GRS Part 5 Road safety for rural and remote areas - Outlines suggested areas where roadside may be used for rest and recuperation

Table A 5: Intersections

Safe road environment features	Road environment element Intersections (at-grade, grade-separated interchanges, rail crossings, traffic signs, roundabouts and priority controlled)
Warn road users of any approaching substandard, unusual or complex features in the road environment that pose an unexpected elevated risk	
Inform road users of the way ahead, and of the type of unusual conditions likely to be encountered	• GRD Part 1 Introduction to road design - Outlines the road design philosophy and principles, why there should be consistency in design and how to address these areas • GRD Part 4 Intersections and crossings: general - Provides general guidance on the design of intersections and how to inform the road user • GRD Part 4A Unsignalised and signalised intersections - Provides guidance on the design of signalised and unsignalised intersections and how to inform the road user • GRD Part 4B Roundabouts - Provides guidance on the design of roundabouts and treatments for vulnerable users and how to inform the road user • GRD Part 4C Interchanges - Provides guidance on the design of interchanges and how to inform the road user
Guide road users along sections of a route and through unusual sections of a route	• GRD Part 4 Intersections and crossings: general - Provides general guidance on the design of intersections and how to guide the road user • GRD Part 4A Unsignalised and signalised intersections - Provides guidance on the design of signalised and unsignalised intersections and how to guide the road user • GRD Part 4B Roundabouts - Provides guidance on the design of roundabouts and treatments for vulnerable users and how to guide the road user • GRD Part 4C Interchanges - Provides guidance on the design of interchanges and how to guide the road user • GTM Part 6 Intersections, interchanges and crossings - Gives guidance on the selection of intersection type to guide the road user • GTM Part 8 Local area traffic management - Gives guidance on the selection of a management plan to guide the road user at intersections
Control road users at conflict points or areas of conflict, and manage their speed	• GTM Part 8 Local area traffic management - Gives guidance on the selection of a management plan to control the road user at intersections
Forgive errant road user inappropriate behaviour or mistakes, with the severity of consequences being minimised	• GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements at the intersection • GRS Part 8 Treatment of crash locations - Outlines the diagnosis and treatment of locations, taking into consideration factors such as the intersection and whether it is forgiving • NZTA RSA - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements at the intersection

Safe road environment features	Road environment element
	Intersections (at-grade, grade-separated interchanges, rail crossings, traffic signs, roundabouts and priority controlled)
No surprise to the road user, where reliable and consistent responses and performance may be expected	• GRD Part 4 Intersections and crossings: general - Provides general guidance on the design of intersections and how to ensure consistency • GTM Part 6 Intersections, interchanges and crossings - Gives guidance on the selection of intersection type which is consistent with what is expected • GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the consistencies in the road designs at intersections • NZTA RSA - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the consistencies in the road designs at intersections
Controlled release through avoidance of road user information overload	• GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration road user information elements at intersections • NZTA RSA - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration road user information elements at intersections
Repeat information to ensure that crucial information is unlikely to be missed, overlooked or forgotten by road users	
Meet expectations of the road user by ensuring similar situations are treated in a similar manner, based on their expectations built up from previous experiences	
Friction supply through reasonable and predictable surface friction requirements, and facilitate recovery from emergencies	
Rest and recuperation areas for road users to avoid the effects of fatigue, particularly on longer trips on rural highways	

Table A 6: Traffic controls

Safe road environment features	Road environment element
	Traffic controls (speed limits, traffic signals, marked crossings, medians, kerb extensions, humps)[(1)]
Warn road users of any approaching substandard, unusual or complex features in the road environment that pose an unexpected elevated risk	

Safe road environment features	Road environment element
	Traffic controls (speed limits, traffic signals, marked crossings, medians, kerb extensions, humps)[(1)]
Inform road users of the way ahead, and of the type of unusual conditions likely to be encountered	
Guide road users along sections of a route and through unusual sections of a route	• AS 1742.3 Traffic control for works on road - Details what signs and devices are used to guide traffic for work sites on the road • GTM Part 5 Road management - Gives guidance on choosing safe speed limits to guide the road user • GTM Part 8 Local area traffic management - Gives guidance on the selection of a management plan to guide the road user • GTM Part 9 Traffic operations - Gives guidance on the use of variable speed limits and signs to guide the user • GTM Part 10 Traffic control and communication devices - Gives guidance on speed signage, traffic signs, electric signs and traffic signals for the guidance of the road user
Control road users at conflict points or areas of conflict, and manage their speed	• AS 1742.3 Traffic control for works on road - Details what signs and devices are used to control traffic for work sites on the road • AS 1742.7 Railway crossings - Details control devices that are used at railway crossings for road users including pedestrians and bicycles • AS 1742.10 Pedestrian control and protection - Details traffic control measures for pedestrians • AS 1742.13 Local area traffic management - Details traffic control devices and their applications in the use of local area traffic management • AS 1742.14 Traffic signals - Details the use of signals as a traffic control device • GTM Part 5 Road management - Gives guidance of choosing safe speed limits to control the road user • GTM Part 8 Local area traffic management - Gives guidance on the selection of local area traffic management plans and schemes to control the road user • GTM Part 9 Traffic operations - Gives guidance on systems and procedures for traffic control • GTM Part 10 Traffic control and communication devices - Gives guidance on traffic signs, electronic signs, traffic signals and traffic islands and their use as traffic control devices • GRS Part 3 Speed limits and speed management - Gives guidance on choosing a safe speed limit to control the road user
Forgive errant road user inappropriate behaviour or mistakes, with the severity of consequences being minimised	• GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking the traffic controls into consideration • GRS Part 8 Treatment of crash locations - Outlines the diagnosis and treatment of locations, taking into consideration factors such as the traffic controls and whether they are forgiving • NZTA RSA - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking the traffic controls into consideration

Safe road environment features	Road environment element
	Traffic controls (speed limits, traffic signals, marked crossings, medians, kerb extensions, humps)[1]
No surprise to the road user, where reliable and consistent responses and performance may be expected	• GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as consistencies in traffic controls • NZTA RSA - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as consistencies in traffic controls
Controlled release through avoidance of road user information overload	• AS 1742.2 Traffic control devices for general use – Outlines the typical arrangement of traffic control devices are and where to put them to avoid information overload • GTM Part 5 Road management – Gives guidance on lane management and speed limits to avoiding information overload • GTM Part 8 Local area traffic management – Gives guidance on the selection of management plans to which can enable a controlled release of information • GTM Part 9 Traffic operations – Gives guidance on systems and procedures for traffic control which enables controlled release of information • GTM Part 10 Traffic control and communication devices – Gives guidance on traffic signs, electronic signs, traffic signals and traffic islands and their use as traffic control devices which helps to enable a controlled release of information • GRS Part 6 Road safety audit – Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration road user information at traffic controls • NZTA RSA – Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration road user information at traffic controls
Repeat information to ensure that crucial information is unlikely to be missed, overlooked or forgotten by road users	• AS 1742.2 Traffic control devices for general use – Outlines the typical arrangement of traffic control devices and layout required are to ensure the information is not missed • GTM Part 5 Road management – Gives guidance on lane management and speed limits to ensure information is not missed • GTM Part 8 Local area traffic management – Gives guidance on traffic signs, electronic signs, traffic signals and traffic islands and their use as traffic control devices to ensure the road user does not overlook information • GTM Part 9 Traffic operations – Gives guidance on systems and procedures for traffic control which helps to enables placement so information is not missed • GTM Part 10 Traffic control and communication devices - Gives guidance on traffic signs, electronic signs, traffic signals and traffic islands and their use as traffic control devices which helps to enable the information to be conveyed to the road user • GRS Part 3 Speed limits and speed management - Gives guidance on choosing a safe speed limit and how to ensure the speed limit is not overlooked

Safe road environment features	Road environment element
	Traffic controls (speed limits, traffic signals, marked crossings, medians, kerb extensions, humps)[(1)]
Meet expectations of the road user by ensuring similar situations are treated in a similar manner, based on their expectations built up from previous experiences	• AS 1742.2 Traffic control devices for general use - Outlines the typical arrangement of traffic control devices should be to ensure that they meet expectations of the road user • GTM Part 5 Road management - Gives guidance on choosing safe speed limits in a manner that meets the expectations of the road user • GTM Part 8 Local area traffic management - Gives guidance on traffic signs, electronic signs, traffic signals and traffic islands and their use as traffic control devices to ensure that they are in used in similar situations • GTM Part 9 Traffic operations - Gives guidance on systems and procedures for traffic control which is in line with the expectations of the road user based on previous experience • GTM Part 10 Traffic control and communication devices - Gives guidance on traffic signs, electronic signs, traffic signals and traffic islands and their use as traffic control devices which is in line with the expectations of the road user based on previous experience • GRS Part 3 Speed limits and speed management - Gives guidance on choosing a safe speed limit and how to ensure the speed limit meets the expectations of the road user
Friction supply through reasonable and predictable surface friction requirements, and facilitate recovery from emergencies	
Rest and recuperation areas for road users to avoid the effects of fatigue, particularly on longer trips on rural highways	

1 *Can be used for speed management.*

Table A 7: Signs

Safe road environment features	Road environment element
	Signs (regulatory, warning, directional, information)[(1)]
Warn road users of any approaching substandard, unusual or complex features in the road environment that pose an unexpected elevated risk	• AS 1742.1 General introduction - Outlines the different signs that are used to warn the road user • AS 1742.2 Traffic control devices for general use - Outlines general traffic control devices at expressway and non-expressway intersections to warn the road user • AS 1742.3 Traffic control for works on roads - Outlines signs used for approach and departure of work sites to warn the road user • AS 1742.10 Pedestrian control and protection - Outlines signage used to warn and protect pedestrians and the road user • GTM Part 8 Local area traffic management - Gives guidance on traffic signs and electronic signs and their use to warn the road user

Safe road environment features	Road environment element
	Signs (regulatory, warning, directional, information)[1]

Inform road users of the way ahead, and of the type of unusual conditions likely to be encountered	• AS 1742.1 General introduction
	  - Outlines the different signs that are used to inform the road user
	• AS 1742.15 Direction signs, information signs and route numbering
	  - Gives guidance on signs that give directions and information to inform the road user
	• GTM Part 8 Local area traffic management
	  - Gives guidance on traffic signs and electronic signs and their use to inform the road user
	• GTM Part 10 Traffic control and communication devices
	  - Gives guidance on electronic signs and their use to inform the road user

Guide road users along sections of a route and through unusual sections of a route	• AS 1742.1 General introduction
	  - Outlines the different signs that are used to guide the road user
	• AS 1742.5 Street name and community facility name signs
	  - Outlines the different signs for street names which are used to guide the road user
	• AS 1742.6 Tourist and services signs
	  - Outlines the different signs that are used for tourist destinations and services which are used to guide the road user
	• AS 1742.7 Railway crossings
	  - Details the signs that are used to guide road users, pedestrians and bicycles at railway crossings
	• AS 1742.9 Bicycle facilities
	  - Details the signs that are used for bicycle facilities to guide the cyclist and road user
	• AS 1742.15 Direction signs, information signs and route numbering
	  - Gives guidance on signs that give directions and information to guide the road user
	• GTM Part 8 Local area traffic management
	  - Gives guidance on traffic signs and electronic signs and their use to guide the road user
	• GTM Part 10 Traffic control and communication devices
	  - Gives guidance on signs and electric signs with the purpose of guiding the road user

Safe road environment features	Road environment element
	Signs (regulatory, warning, directional, information)[1]
Control road users at conflict points or areas of conflict, and manage their speed	• AS 1742.1 General introduction - Outlines the different signs that are used to control the road user • AS 1742.2 Traffic control devices for general use - Outlines general traffic control devices at expressway and non-expressway intersections to control the road user • AS 1742.3 Traffic control for works on roads - Outlines signs that are used to control for roadworks • AS 1742.4 Speed controls - Outlines speed limit signs and their application for controlling the road user • AS 1742.7 Railway crossings - Outlines signs used at railway crossings to control pedestrians, cyclists and road users • AS 1742.10 Pedestrian control and protection - Outlines signs to control the road user and protect pedestrians • AS 1742.12 Bus, transit, tram and truck lanes - Outlines signs to control the bus, transit and truck lanes • AS 1742.13 Local area traffic management - Outlines the signs that are used to control residential areas • AS 1742.14 Traffic signals - Outlines the required signs to control the road user at traffic signals • GRS Part 8 Treatment of crash locations - Gives guidance on traffic signs and electronic signs and their use to control the road user • GTM Part 10 Traffic control and communication devices - Gives guidance on signs and electric signs with the purpose of controlling the road user
Forgive errant road user inappropriate behaviour or mistakes, with the severity of consequences being minimised	
No surprise to the road user, where reliable and consistent responses and performance may be expected	• GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the signs and information presented • NZTA RSA - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the signs and information presented
Controlled release through avoidance of road user information overload	• AS 1742.13 Local area traffic management - Informs of the typical placement of signs to help avoid information overload • GTM Part 8 Local area traffic management - Gives guidance on whether the local area signs are appropriate to ensure there is no information overload • GTM Part 10 Traffic control and communication devices - Gives guidance on signs and electric signs, the location and placement so that the road user does not get an overload of information • GRS Part 6 Road safety audit - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the signs and information presented • NZTA RSA - Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the signs and information presented

Safe road environment features	Road environment element
	Signs (regulatory, warning, directional, information)(1)
Repeat information to ensure that crucial information is unlikely to be missed, overlooked or forgotten by road users	• AS 1742.13 Local area traffic management - Outlines the typical placement of signs to ensure that the information is not missed • GTM Part 8 Local area traffic management - Gives guidance on traffic signs to ensure that the road user does not overlook the signs • GTM Part 10 Traffic control and communication devices - Gives guidance on signs and electric signs, the location and placement so that the road user does not miss crucial information
Meet expectations of the road user by ensuring similar situations are treated in a similar manner, based on their expectations built up from previous experiences	• AS 1742.13 Local area traffic management - Outlines how the signs are to meet the expectations of the road user • GTM Part 8 Local area traffic management - Gives guidance on traffic signs to ensure that they meet the expectations of the road user • GTM Part 10 Traffic control and communication devices - Gives guidance on signs and electric signs, the location and placement so that they meet the expectations of the road user
Friction supply through reasonable and predictable surface friction requirements, and facilitate recovery from emergencies	
Rest and recuperation areas for road users to avoid the effects of fatigue, particularly on longer trips on rural highways	▪ GRS Part 5 Road safety for rural and remote areas - Outlines suggested areas where the roadside may be used for rest and recuperation

1 *Can be used for speed management.*

Table A 8: Markings

Safe road environment features	Road environment element
	Markings (longitudinal and transverse lines, arrows, numerals) **Delineation (lines, guideposts, reflectors, raised pavement markers)**
Warn road users of any approaching substandard, unusual or complex features in the road environment that pose an unexpected elevated risk	• AS 1742.13 Local area traffic management - Outlines the road markings that are used to warn road users of local area traffic management treatments
Inform road users of the way ahead, and of the type of unusual conditions likely to be encountered	• AS 1742.13 Local area traffic management - Describes the road markings that are used to inform road user in the local area environment • GTM Part 8 Local area traffic management - Gives guidance on the markings that can be used to inform the road user of various local area traffic management devices • GTM Part 10 Traffic control and communication devices - Gives guidance on the use of pavement markings to inform road users of conditions they will encounter

Safe road environment features	Road environment element Markings (longitudinal and transverse lines, arrows, numerals) Delineation (lines, guideposts, reflectors, raised pavement markers)
Guide road users along sections of a route and through unusual sections of a route	• AS 1742.2 Traffic control devices for general use - Outlines the use of pavement markings at expressways, ramps, non-expressway intersections, between intersections and in general, to guide the road user • AS 1742.7 Railway crossings - Outlines the use of pavement markings at railway crossings to guide the road user, pedestrians and cyclists • AS 1742.9 Bicycle facilities - Outlines the use of pavement markings to guide cyclists • AS 1742.14 Traffic signals - Outlines the use of pavement markings to guide the road user at traffic signals • GTM Part 8 Local area traffic management - Gives guidance on the markings that can be used to guide the road user at various local area traffic management devices • GTM Part 10 Traffic control and communication devices - Gives guidance on the use of pavement markings to guide the road user along the road including the use of audio-tactile markings to address fatigue issues
Control road users at conflict points or areas of conflict, and manage their speed	• AS 1742.4 Speed controls - Outlines pavement markings with the purpose of controlling speed • AS 1742.7 Railway crossings - Outlines pavement markings with the purpose of controlling the road user at railway crossings • AS 1742.10 Pedestrian control and protection - Outlines the pavement markings used for pedestrian control • AS 1742.12 Bus, transit, tram and truck lanes - Outlines the use of pavement markings for controlling bus, transit and truck lanes • AS 1742.13 Local area traffic management - Outlines the use of road markings that are used to control road users in the local area environment • GTM Part 8 Local area traffic management - Gives guidance on the markings that can be used to control the road user at various local area traffic management devices • GTM Part 10 Traffic control and communication devices - Gives guidance on the use of pavement markings to control the road user
Forgive errant road user inappropriate behaviour or mistakes, with the severity of consequences being minimised	• GRS Part 8 Treatment of crash locations - Gives guidance on how to diagnose the cause of crashes and rectify the situation
No surprise to the road user, where reliable and consistent responses and performance may be expected	• GRS Part 6 Road safety audit – Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as road markings • NZTA RSA – Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as road markings

Safe road environment features	Road environment element Markings (longitudinal and transverse lines, arrows, numerals) Delineation (lines, guideposts, reflectors, raised pavement markers)
Controlled release through avoidance of road user information overload	• AS 1742.13 Local area traffic management – Outlines the road markings that are used to control the road user in the local area environment which ensures that the road user is not overloaded with information • GTM Part 8 Local area traffic management – Gives guidance on the markings that can be used to control the road user at various local area traffic management devices which ensures that the road user is not overloaded with information • GTM Part 10 Traffic control and communication devices – Gives guidance on the use of pavement markings to control the road user which ensures that the road user is not overloaded with information • GRS Part 6 Road safety audit – Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the road markings • NZTA RSA – Outlines how to undertake a road safety audit to ensure safety in planning and design, taking into consideration elements such as the road markings
Repeat information to ensure that crucial information is unlikely to be missed, overlooked or forgotten by road users	• AS 1742.13 Local area traffic management - Outlines the road markings that are used to control road users in the local area in a way that it is not likely to result in the road user being overloaded • GTM Part 8 Local area traffic management - Gives guidance on the markings that can be used to control the road user in a way that ensures that road users are not overloaded • GTM Part 10 Traffic control and communication devices - Gives guidance on the use of pavement markings and how to convey the information
Meet expectations of the road user by ensuring similar situations are treated in a similar manner, based on their expectations built up from previous experiences	• AS 1742.13 Local area traffic management - Outlines the road markings that are used to control road users in the local area environment which is consistent with previous experiences of the road user • GTM Part 8 Local area traffic management - Gives guidance on the markings that can be used to control the road user at various local area traffic management devices which is consistent with previous experiences of the road user • GTM Part 10 Traffic control and communication devices - Gives guidance on the use of pavement markings to control the road user in a manner which is consistent with previous experiences of the road user
Friction supply through reasonable and predictable surface friction requirements, and facilitate recovery from emergencies	
Rest and recuperation areas for road users to avoid the effects of fatigue, particularly on longer trips on rural highways	

Table A 9: Lighting

Safe road environment features	Road environment element Lighting (route lighting, local street and pathways lighting)
Warn road users of any approaching substandard, unusual or complex features in the road environment that pose an unexpected elevated risk	
Inform road users of the way ahead, and of the type of unusual conditions likely to be encountered	• AS/NZS 1158 Lighting for roads and public spaces - Part 0 gives a general introduction on lighting - Part 1 gives a guide for design, operation and maintenance of lighting - Part 2 gives procedures for calculation of lighting parameters using computers - Part 3 covers performance and design requirements of lighting - Part 4 covers lighting of pedestrian crossings - Part 5 covers lighting of tunnels and underpasses - Part 6 covers luminaires • GRD Part 6B Roadside environment - Gives guidance on how to install road lighting to inform the road user
Guide road users along sections of a route and through unusual sections of a route	• AS/NZS 1158 Lighting for roads and public spaces - Part 0 gives a general introduction on lighting - Part 1 gives a guide for design, operation and maintenance of lighting - Part 2 gives procedures for calculation of lighting parameters using computers - Part 3 covers performance and design requirements of lighting - Part 4 covers lighting of pedestrian crossings - Part 5 covers lighting of tunnels and underpasses - Part 6 covers luminaires • GRD Part 6B Roadside environment - Gives guidance on how to install road lighting to guide the road user
Control road users at conflict points or areas of conflict, and manage their speed	
Forgive errant road user inappropriate behaviour or mistakes, with the severity of consequences being minimised	
No surprise to the road user, where reliable and consistent responses and performance may be expected	• AS/NZS 1158 Lighting for roads and public spaces - Part 0 gives a general introduction on lighting - Part 1 gives a guide for design, operation and maintenance of lighting - Part 2 gives procedures for calculation of lighting parameters using computers - Part 3 covers performance and design requirements of lighting - Part 4 covers lighting of pedestrian crossings - Part 5 covers lighting of tunnels and underpasses - Part 6 covers luminaires
Controlled release through avoidance of road user information overload	
Repeat information to ensure that crucial information is unlikely to be missed, overlooked or forgotten by road users	

Safe road environment features	Road environment element
	Lighting (route lighting, local street and pathways lighting)
Meet expectations of the road user by ensuring similar situations are treated in a similar manner, based on their expectations built up from previous experiences	
Friction supply through reasonable and predictable surface friction requirements, and facilitate recovery from emergencies	
Rest and recuperation areas for road users to avoid the effects of fatigue, particularly on longer trips on rural highways	

Appendix B Safe System Assessment Framework

The Safe System assessment framework as defined in Austroads (2016a) is completed by assigning a score of between zero and four to each cell in the matrix as indicated in Table B 1. A score of zero indicates that the system is fully aligned with the Safe System vision for that component of a given crash type. The higher the score, the further the project is from a Safe System condition. Scores should be allocated considering the factors of interest shown in the matrix and the scoring system shown in Table B 2. It should be noted that some elements can be included in either crash exposure, likelihood or severity, as they may affect either in each situation.

In addition to the score, comments can be added to each of the cells to help identify the specific issues of concern. This is very helpful in determining the key risk factors for each project.

Once there is a score in each cell for the exposure, likelihood and severity rows, the product of each column is calculated and entered in the final row, labelled total. The purpose of this multiplicative approach is that if a score of zero has been given for any component of a crash type (i.e. exposure, likelihood or severity), that crash type receives a total of zero and is eliminated from the score (as it has reached a Safe System). The sum of the infrastructure total scores for each crash type is then added to the final cell on the right-hand side (with the bold border). This score is out of a possible 448 and represents the safer speeds, safer roads and roadsides pillars. The closer the score is to zero, the more the project in question is in alignment with Safe System principles.

Additional Safe System pillars (i.e. road users, vehicles and post-crash care) are considered in the following rows, where prompts are given to direct the users to consider how the project relates/interacts with road users and vehicles, and vice versa. It also gives the user the opportunity to consider additional actions, such as automated enforcement or regulatory restrictions on vehicle access.

The outcomes from this assessment should be recorded, and added to the content on objectives and context to form the assessment report. Examples of such reports can be found in Austroads (2016a).

The assessment framework should not be used as a method of directly comparing different sites but rather is better suited to comparing options at a single site, identifying sources of risk and identifying solutions.

The scoring system produces results that indicate increasing or decreasing risk (i.e. the higher the score, the higher the risk). Changes in score indicate only a likely change in risk, and not the exact magnitude of that change.

Table B 1: Safe System matrix for safe roads and safe speeds

	Run-off-road	Head-on	Intersection	Other	Pedestrian	Cyclist	Motorcyclist	
Exposure	/4	/4	/4	/4	/4	/4	/4	
Likelihood	/4	/4	/4	/4	/4	/4	/4	
Severity	/4	/4	/4	/4	/4	/4	/4	
Product	/64	/64	/64	/64	/64	/64	/64	/448

Additional Safe System components		
	Prompts	**Comments**
Road user	Are road users likely to be alert and compliant? Are there factors that might influence this? What are the expected compliance and enforcement levels (alcohol/drugs, speed, road rules, and driving hours)? What is the likelihood of driver fatigue? Can enforcement of these issues be conducted safely? Are there special road uses (e.g. entertainment precincts, elderly, children, on-road activities, motorcyclist route), distraction by environmental factors (e.g. commerce, tourism), or risk-taking behaviours?	
Vehicle	What level of alignment is there with the ideal of safer vehicles? Are there factors which might attract large numbers of unsafe vehicles? Is the percentage of heavy vehicles too high for the proposed/existing road design? Is this route used by recreational motorcyclists? Are there enforcement resources in the area to detect unroadworthy, overloaded or unregistered vehicles and thus remove them from the network? Can enforcement of these issues be conducted safely? Has vehicle breakdown been catered for?	
Post-crash care	Are there issues that might influence safe and efficient post-crash care in the event of a severe injury (e.g. congestion, access stopping space)? Do emergency and medical services operate as efficiently and rapidly as possible? Are other road users and emergency response teams protected during a crash event? Are drivers provided the correct information to address travelling speeds on the approach and adjacent to the incident? Is there reliable information available via radio, VMS etc.? Is there provision for e-safety (i.e. safety systems based on modern information and communication technologies, C-ITS)?	

Source: Austroads (2016a).

Table B 2: Safe System matrix scoring system

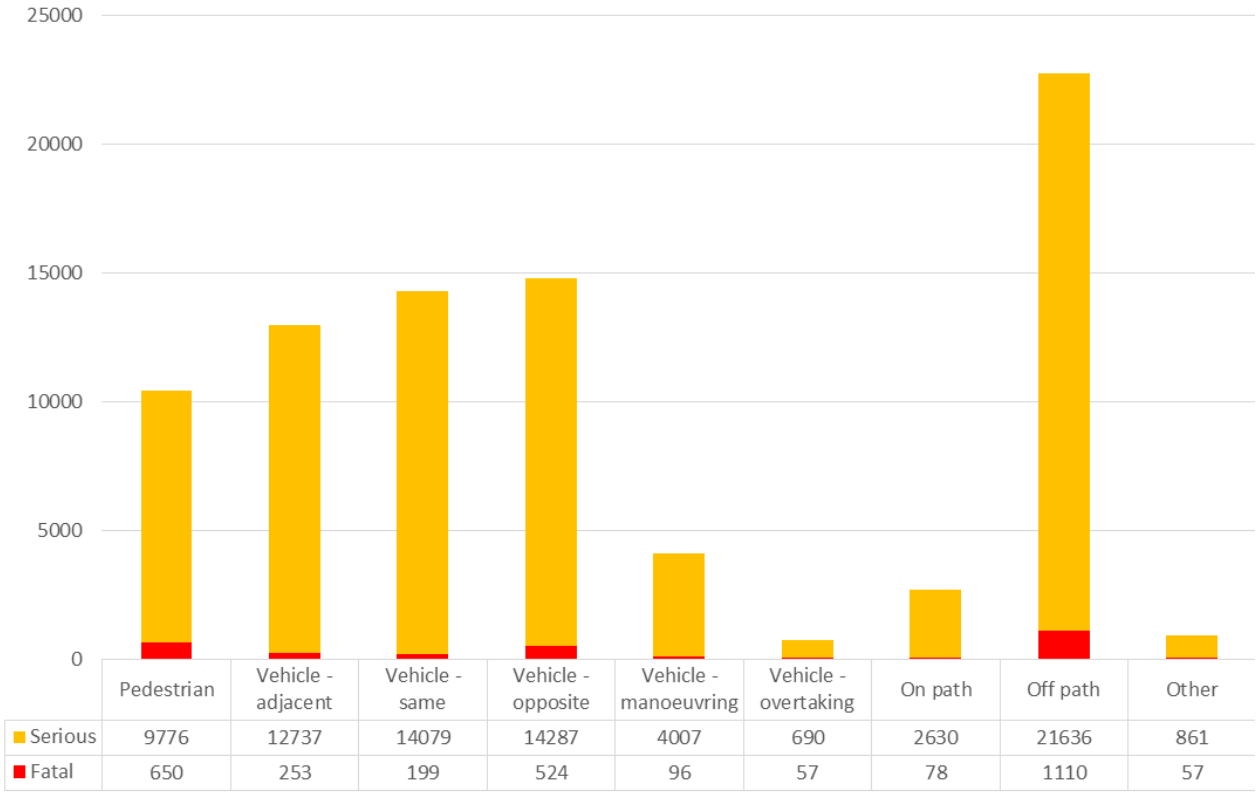
Road user exposure	Crash likelihood	Crash severity
0 = there is no exposure to a certain crash type. This might mean there is no side flow or intersecting roads, no cyclists, no pedestrians, or motorcyclists.	0 = there is only minimal chance that a given crash type can occur for an individual road user given the infrastructure in place. Only extreme behaviour or substantial vehicle failure could lead to a crash. This may mean, for example, that two traffic streams do not cross at grade, or that pedestrians do not cross the road.	0 = should a crash occur, there is only minimal chance that it will result in a fatality or serious injury to the road user involved. This might mean that kinetic energies transferred during the crash are low enough not to cause a fatal or serious injury (FSI), or that excessive kinetic energies are effectively redirected/dissipated before being transferred to the road user. Users may refer to Safe System critical impact speeds for different crash types, while considering impact angles, and types of roadside hazards/barriers present.
1 = volumes of vehicles that may be involved in a crash type are particularly low, and therefore exposure is low. For run-off-road, head-on, intersection and other crash types, AADT is < 1 000 per day. For cyclist, pedestrian and motorcycle crash types, volumes are < 10 units per day.	1 = it is highly unlikely that a given crash type will occur.	1 = should a crash occur, it is highly unlikely that it will result in a fatality or serious injury to any road user involved. Kinetic energies must be low during a crash, or the majority is effectively dissipated before reaching the road user.
2 = volumes of vehicles that may be involved in a crash type are moderate, and therefore exposure is moderate. For run-off-road, head-on, intersection and other crash types, AADT is between 1 000 and 5 000 per day. For cyclist, pedestrian and motorcycle crash types, volumes are 10–50 units per day.	2 = it is unlikely that a given crash type will occur.	2 = should a crash occur, it is unlikely that it will result in a fatality or serious injury to any road user involved. Kinetic energies are moderate, and most of the time they are effectively dissipated before reaching the road user.
3 = volumes of vehicles that may be involved in a crash type are high, and therefore exposure is high. For run-off-road, head-on, intersection and other crash types, AADT is between 5 000 and 10 000 per day. For cyclist, pedestrian and motorcycle crash types, volumes are 50–100 units per day.	3 = it is likely that a given crash type will occur.	3 = should a crash occur, it is likely that it will result in a fatality or serious injury to any road user involved. Kinetic energies are moderate, but are not effectively dissipated and therefore may or may not result in an FSI.
4 = volumes of vehicles that may be involved in a crash type are very high, or the road is very long, and therefore exposure is very high. For run-off-road, head-on, intersection and other crash types, AADT is > 10 000 per day. For cyclist, pedestrian and motorcycle crash types, volumes are > 100 units per day.	4 = the likelihood of individual road user errors leading to a crash is high given the infrastructure in place (e.g. high approach speed to a sharp curve, priority movement control, filtering right-turn across several opposing lanes, high-speed).	4 = should a crash occur, it is highly likely that it will result in a fatality or serious injury to any road user involved. Kinetic energies are high enough to cause an FSI crash, and it is unlikely that the forces will be dissipated before reaching the road user.

Source: Austroads (2016a).

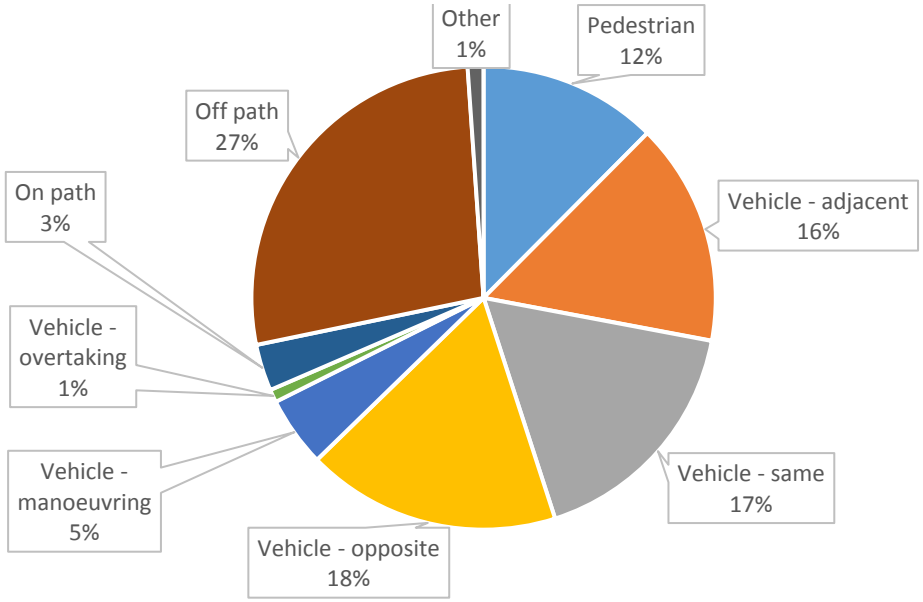
Appendix C Road Fatalities and Serious Injuries

Austroads (2015f) provides an overview of FSI crashes in urban and rural road environments by crash type in both Australia and New Zealand. Figures presented in graphs, based on this information is outlined in Figure C 1 through to Figure C 4.

Figure C 1: Fatal and serious injury crashes in urban Australian environments by crash type, 2006–10

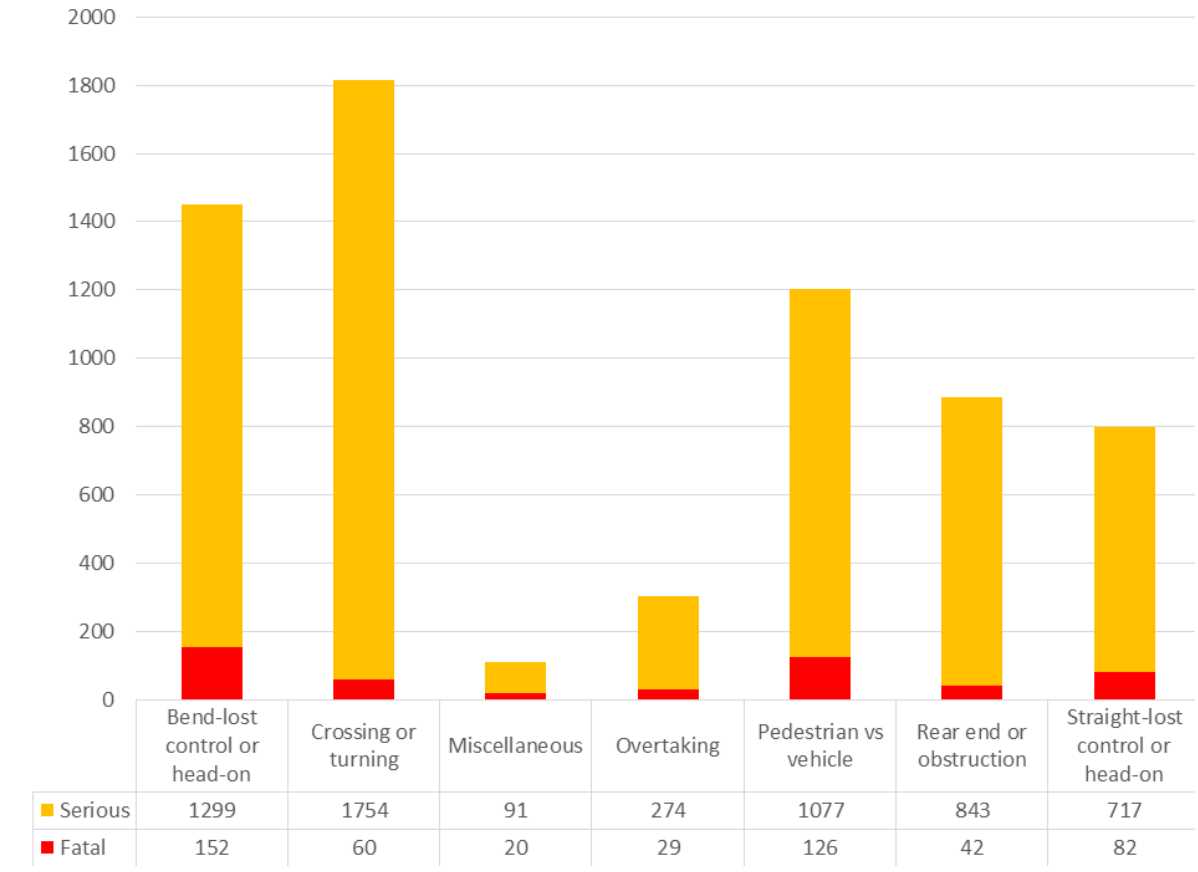


	Pedestrian	Vehicle - adjacent	Vehicle - same	Vehicle - opposite	Vehicle - manoeuvring	Vehicle - overtaking	On path	Off path	Other
Serious	9776	12737	14079	14287	4007	690	2630	21636	861
Fatal	650	253	199	524	96	57	78	1110	57

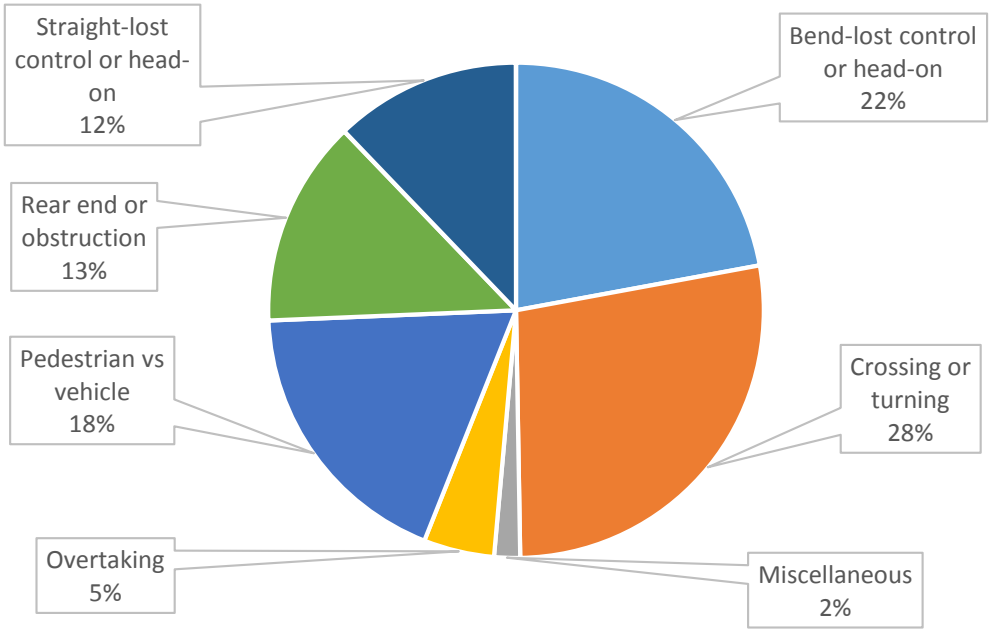


Source: Austroads (2015f).

Figure C 2: Fatal and serious injury crashes in urban New Zealand environments by crash type, 2006–10

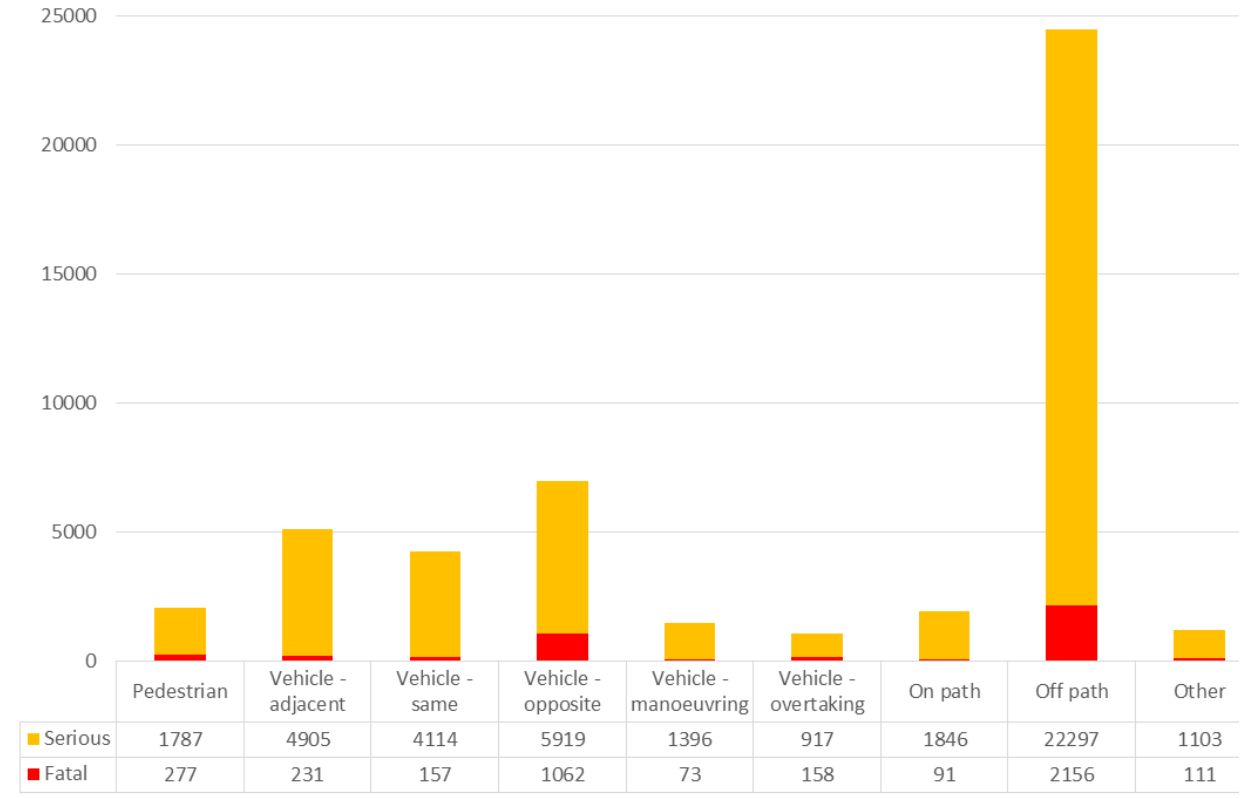


	Bend-lost control or head-on	Crossing or turning	Miscellaneous	Overtaking	Pedestrian vs vehicle	Rear end or obstruction	Straight-lost control or head-on
Serious	1299	1754	91	274	1077	843	717
Fatal	152	60	20	29	126	42	82

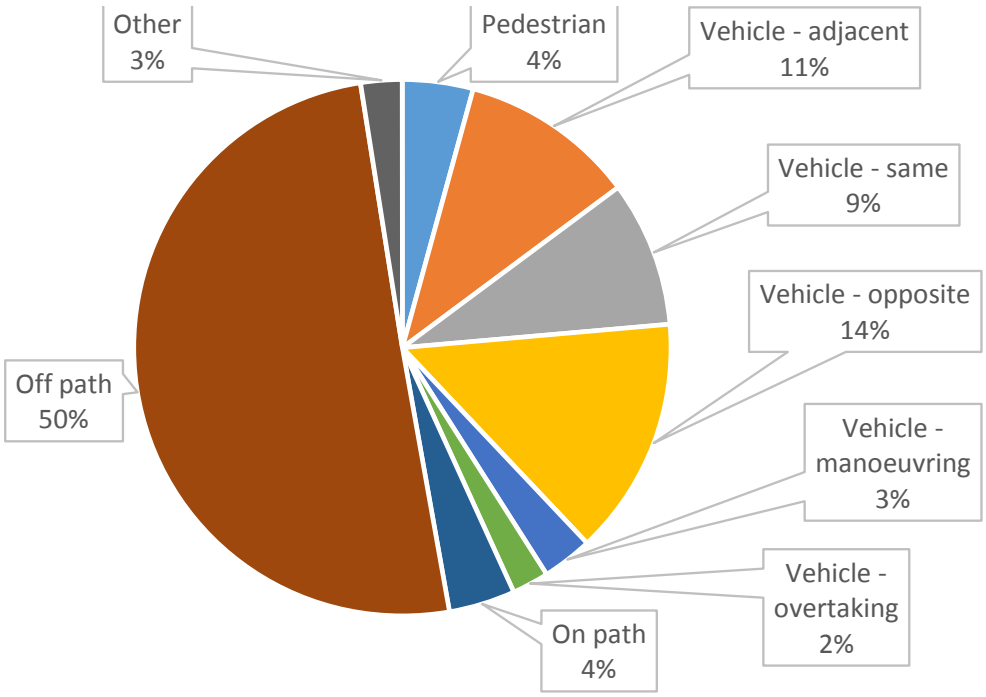


Source: Austroads (2015f).

Figure C 3: Fatal and serious injury crashes in rural Australian environments by crash type, 2006–10

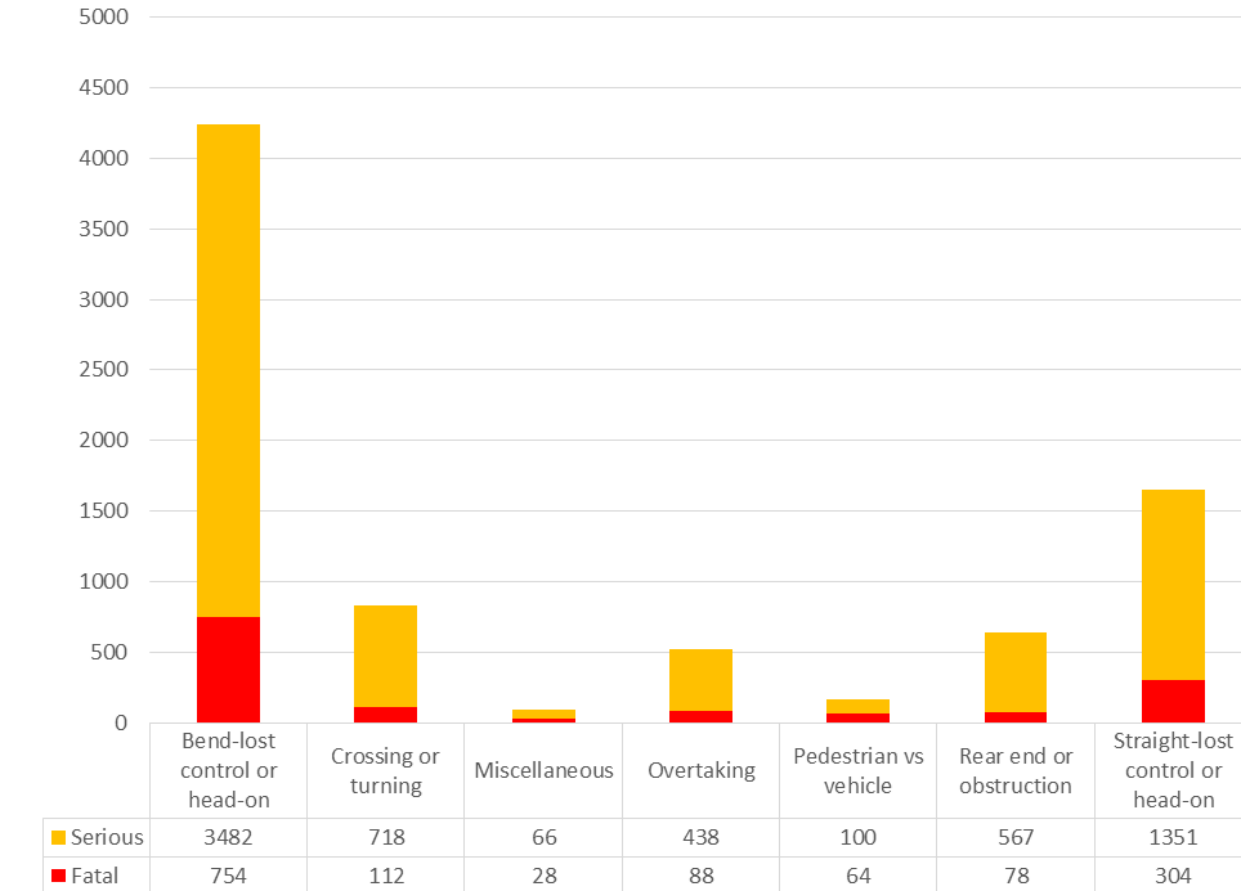


	Pedestrian	Vehicle - adjacent	Vehicle - same	Vehicle - opposite	Vehicle - manoeuvring	Vehicle - overtaking	On path	Off path	Other
Serious	1787	4905	4114	5919	1396	917	1846	22297	1103
Fatal	277	231	157	1062	73	158	91	2156	111

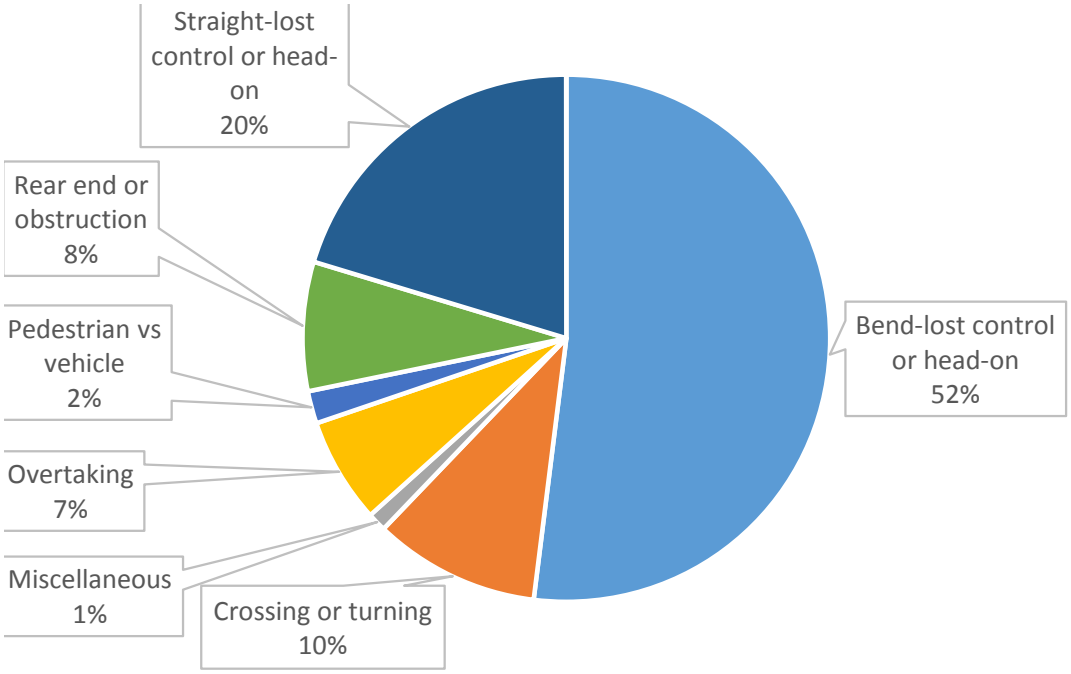


Source: Austroads (2015f).

Figure C 4: Fatal and serious injury crashes in rural New Zealand environments by crash type, 2006–10



	Bend-lost control or head-on	Crossing or turning	Miscellaneous	Overtaking	Pedestrian vs vehicle	Rear end or obstruction	Straight-lost control or head-on
Serious	3482	718	66	438	100	567	1351
Fatal	754	112	28	88	64	78	304



Source: Austroads (2015f).

Appendix D Human Factors

The road system needs to make allowance for human factors, the factors that need to be catered for are discussed in the following section.

D.1 Types of Human Factors That May Contribute to Crashes

Humans act in response to signals, or stimuli. This may be described by the basic psychological model of an input-stimulus-decision-response-output mechanism. In a human operated machine environment, the overall model is that of a human-controlled system operating in equilibrium with the demands of the task. But the system does not always operate perfectly; mistakes do occur. The types of human factors that may contribute to crashes include:

- stimuli being missed
- stimuli being ignored
- confusing stimuli
- unexpected stimuli
- stimulus signal-to-noise ratio too low
- an inability to respond
- insufficient time to respond correctly
- missing or inadequate feedback on a previous response.

It is not necessarily the fault of the driver that a stimulus is unexpected, missed, misinterpreted, or responded to incorrectly. The design of the stimulus mechanism, or the system of which it is part, might not have taken due account of the human's role or behaviour – expectations, capabilities and limitations. The essence of the ergonomics approach is to consider those factors in the functional design of the system.

D.2 Human Factors in the Road System

Drivers of vehicles on the road (including motorcyclists and cyclists) and pedestrians receive and process inputs from the operating environment (the road and the vehicle), make predictions and decisions about appropriate actions, execute those actions, and receive feedback about their effects. The driver thus acts as a processing and decision-making centre in the system.

Drivers must perceive and process this information, and make decisions on it, within finite time intervals. Comfortable and safe driving occurs when they are operating well below a stressful processing and decision-making rate and above a minimum level of arousal.

Driver-related errors may occur because of:

- inadequate or insufficient inputs (missed stimuli), (e.g. night driving, poor sight distances)
- driver difficulty in handling extreme inputs or uncommon events (unexpected stimuli), (e.g. gravel or wet roads)
- inadequate sampling or slow processing of inputs (insufficient time to process), (e.g. because of distraction)
- misjudgements in decisions related to driver stress, arousal, conditioning, impairment, experience, motivation, and type of input.

D.3 Human Factors and System Design

The human factor elements frequently related to crashes are the perception and processing of information presented by the road and traffic environment. This can suggest that the demands of the driving situation may be more than the driver can handle, and raises the question of what gives rise to those high demands.

In crash studies, it is too simplistic to assume that when a crash occurs, if a vehicle met the manufacturer's standards, the possibility of a vehicle problem can be eliminated; or if the roadway met the (minimum) design requirements the possibility of a roadway problem can be ruled out. It is useful to consider if a better braking system on the vehicle might have enabled the driver to avoid the crash; or to judge whether an improved highway design or signing system would have given the driver adequate warning to manoeuvre to avoid the crash.

Road safety researchers and managers have for many years acknowledged that it may be deficiencies in the design of roads, traffic management systems, and vehicles that do not cater for the capabilities and limitations of the driver which can lead ultimately to a system error – a crash.

As a result, and as recognised by PIARC (2015), roads should be designed and managed to take account of human factors, otherwise it is unlikely that a Safe System can be achieved. This can be achieved through meeting the following key requirements identified by PIARC (2015):

- Giving the driver sufficient time to react.
- Providing the road with a safer field of view
  - This may include providing for a greater and wider field of view and sight distance in many instances. This may require restricting the field of view. For example, restricting the field of view to adjacent roads on the approach to a roundabout can force drivers to slow down and therefore lead to a safer road environment as described in criterion 3 of the sight distance requirements for the design of roundabouts as described in the *Guide to Road Design Part 4B: Roundabouts* (Austroads 2015i).
- Designing the road environment so that it corresponds with the road users' perception of logic.

Appendix E Traffic Management, Road Design and the Driver

Road engineering and traffic management practice has been refined over many years by incorporating the results of research into human behaviour into standards and guidelines.

The standards must be met, and application of guidelines provide a good base level of best practice. However, each practical situation is theoretically unique, so the design of the road section or traffic management treatment should be assessed in terms of how road users are likely to respond. Simple application of an acknowledged best practice design might not be completely successful in accommodating a typical road user response.

An accepted principle is that for a given geometric road element, a designer should not adopt the minimum standard for many parameters. That is, a combination of minimum standards may effectively result in an unsafe design, and should be avoided. For example, if the minimum sight distance is provided, then the curvature adopted for a horizontal curve should not be the minimum in the same location.

Although the designer of a layout of signs and markings will know what is intended, the approaching road user might not. Therefore, road users should be warned and informed of road features ahead using appropriate signs and markings as prescribed in the relevant standards and guidelines (refer to Appendix A for standards and guide linkages between safe road environment elements and safe environmental elements). The layout of the signs and markings should therefore reliably deliver the intended message and be checked from the perspective of the naïve road user approaching who will initially be unaware of what is ahead. The designer needs to ask: how could someone misinterpret this layout?

Traffic management systems and facilities are required for road users to control their vehicles safely within the road space and in response to other vehicles and road users. Therefore, traffic managers and road designers need to understand some of the perceptual and information processing capabilities of drivers so that road and traffic management systems may be designed to assist drivers in their task.

Appendix F The Driving Task

The driving task can be subdivided into strategy, navigation, guidance, manoeuvring and control. Strategy refers to factors such as overall route planning and scheduling, navigation relates to route finding, guidance relates to route following, while manoeuvring and control relates to the performance of individual movements in the traffic stream.

The primary objective is to proceed to a destination safely, efficiently and comfortably. The tasks involved are to find the route, proceed in the general traffic stream (generally within constraints), and carry out individual manoeuvres within the constraints.

The tasks require drivers to process information – to sense inputs (mostly visual), interpret and process them, make decisions, execute actions, and observe their effects through the reception and processing of new information. The driver does not operate only in response to discrete and static information inputs or task demands. The system is dynamic – a continually interactive, cyclic process of responding to changing demands and the effects of the response actions themselves.

The driver's task:

- involves mental activity in processing the information received from the environment
- relies on memory and experience to guide decisions about the necessary actions
- involves physical activity in giving effect to those actions.

Performance of the information processing task is influenced not only by the demand of the task itself, and the driver's capabilities, but also by other aspects which characterise human behaviour.

Appendix G Driver Characteristics and Behaviour

Aspects of driver behaviour can be classified as:

- psychological traits (intelligence, learning, skills, motivation, desires, attitudes)
- sensory abilities (vision, hearing)
- physical abilities (perception and reaction times – perception, motor response)
- medical factors (influence of drugs, disease, impairment and emotional stress).

Psychological traits can influence driver behaviour and therefore the vehicle on the road. The driver brings to the task various values, norms, attitudes, motives and expectations based on their experience at performing the task.

Sensory abilities, physical abilities, and medical factors limit the capabilities of road users. Road users cannot process an unlimited amount of information in a short time interval. A finite amount of time, albeit short, is required to process a piece of information. In designing a road section or traffic management treatment, the capabilities and limitations of the users need to be considered, otherwise the demand placed on the users could be too great.

G.1 Capabilities and Limitations

The driver's ability to receive and process information is influenced and limited by several factors, as described below.

G.1.1 Visual Characteristics

Visual characteristics such as the extent of the visual field, peripheral vision, eye and head movements, responses to low illumination and glare, and colour vision defects, play an important part in influencing the receipt of information. The key characteristics of driver visual information needs may be summarised as:

- conspicuity – detecting sources of information
- legibility – recognising the information
- comprehension – interpreting what the information means
- credibility – accepting the information as believable or relevant.

Road and traffic engineers must ensure that the design of the road, and traffic management devices, meets these visual needs. Linkages to parts of the *Guide to Road Design*, the *Guide to Road Safety* and the *Guide to Traffic Management* that provide details on warning, informing and guiding road users through various road elements are outlined in Appendix A.

G.1.2 Perception and Reaction Times (PRT)

The perception and reaction time is the time consumed by a road user between the stimulus and decision/action. Perception and reaction times are typically considered to range between 0.75 seconds to 2.5 seconds, but with a large variance. Some authors consider the range to be 0.5 to 3.5 seconds (Olsen in Dewar & Olsen 2007). Perception and reaction times of 1.5 to 2.5 seconds are typically used for design and analysis purposes.

In traffic safety analysis, it may often be necessary to allow for a vehicle response time – which may range from 0.5 seconds (for cars) to 3 or 4 seconds (for trucks) – in determining the total time before a change in vehicle motion might occur (Homburger & Kell 1989).

A single value of perception-reaction time is not appropriate for all situations, because situations differ, people respond in different ways, and one individual may respond differently from one day to the next.

A road user's perception-reaction time is typically measured from when the road user becomes aware of a stimulus. Perception and reaction is usually divided into four stages – perception, interpretation, judgment and reaction (Viner & English 1995) or detection, identification, decision and response (Dewar & Olsen 2007 and Olsen 2010). These stages overlap to varying extents.

Situations which cause problems with road user perception, interpretation or judgment stages can significantly affect their overall perception and reaction times and may lead to crashes, as summarised in Table G 1.

Table G 1: Factors affecting road user perception-reaction

If traffic management devices (e.g. signals, signs, markings, delineation) or road alignments are:	Road users may:
Poorly located or maintained or too small for the situation (approach speed)	Miss seeing them, or perceive them later than would otherwise be the case
Unusual or unexpected	Take additional time to interpret what they should do next
Excessive (signing), confusing, ambiguous, complex or the sequencing of information is complex e.g. toll value, method of payment, direction	Take longer making decisions or make a wrong decision

Road safety engineering aims to avoid extended perception and reaction times by creating situations where stimuli may be promptly detected and consistently interpreted.

G.1.3 Short-term Memory (STM)

This is the information held in temporary storage while processing earlier inputs. Road users may not be able to retain earlier information while processing later information, especially if the required processing rate is high. This has implications for the sequencing of information in an orderly and timely fashion, and repeating information where necessary.

G.1.4 Expectancies

Presentation of stimuli, such as signs and markings, in standard and expected ways can help reduce reaction times and extend detection distances.

Through experience, a road user builds a store of reference guides relating to the way the road environment is typically presented, and to the behaviour of other road users. These reference levels, or expectancies, guide the road user's subsequent behaviour in response to the road environment. Unusual events or situations violate road user expectancies and can have the effect of significantly prolonging the road user's response to the situation ahead, and can lead to erroneous responses.

G.1.5 Information Processing Capacity

There are limits to human information processing capacity. At high levels of demand, performance (correct responses) falls away and eventually an overload situation is reached where performance deteriorates more rapidly. Under dynamically varying demand, performance after overload remains at a low level until demand reduces sufficiently for performance to match it again. There is a resulting loss of information and performance (Ogden 1996). Alternatively, if demand is too low, the alertness of the driver will be low as well, causing delay in perception and reaction time due to lack of vigilance (Austroads 2015l).

G.1.6 Medical Factors

Medical factors such as physical or mental disabilities, emotional state, or the effects of alcohol, drugs, disease or fatigue can influence information processing abilities. This can accentuate the information loss experienced under high rates of task demand.

G.1.7 Age Related Factors

Age can play a role in the capabilities and limitations of drivers. Drivers aged over 65 years are highly represented in fatal and serious injury (FSI) crashes. The data does not detail whether older drivers are over-exposed to risky situations, their frailty, their driving behaviour or there are other factors at play. Older drivers are safe and cautious drivers, however, as people age there is a decline in sensory, cognitive and motor skills, which can affect the ability to drive safely (Austroads 2003).

Young drivers are also highly represented in road crashes and casualties. Inexperience is the contributing factor as opposed to the age of the driver. Older drivers who are inexperienced also have a higher risk of crashing when transitioning from a learner to an independent driver. The skills that are lacking in novice drivers include hazard perception, attentional control, time sharing and calibration, which take years to develop. The combination of lack of experience and the limited skills increases the impact of risky behaviour (Austroads 2015m).

Commentary 1

Austroads (2013d) reviewed the jurisdictional guidelines for roadside advertisements which were available at the time of publication. It is noted that some jurisdictions have updated their guidelines since, such as DPTI (2014). Based on the considerations outlined in Austroads (2013d), guidance with respect to the design and placement of digital advertising is provided. These are divided into sign design guidance (Table C1 1) and sign placement guidance (Table C1 2). The recommendations are specifically targeted at digital billboards and their potential for distraction, thus should be an addition to existing guidelines relating to conventional billboards.

Table C1 1: Digital advertising sign design guidance

Digital advertising design element	Guidance
Movement	Roadside advertising devices should not contain motion, changes in luminance or any effects that create the illusion of movement.
Flashing lights	Roadside advertising devices should not contain flashing, blinking, revolving, pulsating or intermittent lights.
Dwell time	This should take account of (1) visibility distance [VD]: the maximum distance from the sign at which the sign face becomes visible to drivers and (2) speed environment [SE]. The goal is to limit the number of message changes that drivers are exposed to. Therefore, an advertising device that is visible from 1000 m away on a 60 km/h road needs to have much longer dwell times than an advertising device that is visible only from 100 m away on a 100 km/h road. All drivers will see at least one change if: • dwell time (sec) < VD (m)÷{SE (km/h) x 0.28}. Ideally, the proportion of drivers (PD) who see a change should be much less than 1. Therefore: • dwell time (sec) > VD (m)÷{SE (km/h) x 0.28}. For a desired PD: • dwell time = VD (m)÷{SE (km/h) x 0.28 x PD}.
Transition time	Message should change instantaneously. That is, no fade, zoom or fly-in effects and no blank screen between messages.
Message sequencing	Sequencing of messages should be prohibited.
Quantity of information	For text, this should be consistent with the number of words that can be read during the approach interval and the number of words that can be read in a 2 second interval (the eyes off the road interval at which the crash rate doubles). This can be achieved by (1) estimating the legibility distance [LD]: the distance at which the text first becomes legible, (2) considering approach speed – the speed environment [SE], (3) estimating the comprehension rate [CR], and (4) ensuring that attention of more than 2 seconds is not required to comprehend the message. Therefore: • number of words < LD (m) ÷{ SE (km/h) x 0.28} x CR (sec) • number of words < CR (sec) x 2. In general, a typical comprehension rate would be approximately three words per second, but this will vary for different text sizes, fonts and formats. As a result, the CR may need to be tested and demonstrated in the application process.
Information presentation	Not applicable to advertising devices.
Colour	Advertising devices should not be coloured like an official traffic sign or traffic signals.
Information content/meaning	Advertising devices should not imitate traffic control devices or give instructions to traffic to stop, halt or other (e.g. give way, turn left or merge). Advertising devices should not contain extreme emotional material, especially content which could be threatening or anxiety provoking.
Luminance	Luminance levels should not exceed those of static signs in typical ambient light conditions.
Dimensions	Advertising devices should not be shaped like an official traffic control sign/device.

Source: Austroads (2013d).

Table C1 2: Digital advertising sign placement guidance

Digital advertising placement element	Guidance
Longitudinal placement	Advertising devices should not be in such a way that they might interfere with the effectiveness of a traffic control device (e.g. by restricting sightlines or distracting from traffic control devices via proximity or as a background). Advertising devices should not be located so that they are visible at the approach to, or from, an intersection, pedestrian crossing, tram stop or in any location that is likely to be highly demanding of attention. Only one advertising device should be visible to drivers at any time.
Lateral placement	Without conflicting with clear zone requirements (e.g. installation of a post in a hazardous location), advertising devices should not be placed such that drivers must divert their gaze away from the forward roadway to comprehend the sign message.
Vertical placement	Advertising devices should not be placed at a height that coincides with the normal hazard viewing window that drivers scan. That is, they should be elevated above the height of vehicles, pedestrians and traffic control devices, but not so high that they draw the gaze away from the forward roadway.
Orientation/viewing angle	Advertising devices should be oriented to facilitate legibility from the maximum legibility distance and across the full approach distance.
Sight distance/visibility	Advertising devices should be placed so that enough time is available on approach for drivers to comprehend the message. That is, the sight distance must correspond to the required legibility distance.
Speed limit/speed environment	The speed environment on its own is likely to be less important than the overall risk profile of the road and driving demand characteristic of the road section which should be carefully reviewed.
Other	All installations should consider the overall risk profile of the road environment in question and the driver demand of the road section (e.g. crash history, AusRAP ratings, traffic volume, speed, complexity, clutter). In particular: • Black spots and road sections with less than a 3-star rating (AusRAP or equivalent) should be ruled out for advertising device placement. • Highly cluttered road environments should be ruled out for advertising device placement. • The installation should be reviewed at regular intervals and audited against the guidance principles (because crash rates, traffic volume, the built environment etc. will change over time). • Advertising signs should not be placed on the same posts as traffic control devices.

Source: Austroads (2013d).

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Austroads' Guide to Traffic Management consists of 13 parts and provides comprehensive coverage of traffic management guidance for practitioners involved in traffic engineering, road design and road safety.

Guide to Traffic Management Part 13: Road Environment Safety is concerned with traffic management practice under the Safe System philosophy. The Guide emphasises the need for the road system to provide an environment which assists road users to behave effectively and safely. It considers the role of traffic management in influencing road user behaviour and provides specific guidance for practitioners on the road safety aspects of traffic management.

Guide to Traffic Management Part 13

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