GUIDE TO TRAFFIC MANAGEMENT

Part 13: Road Environment Safety

Austroads

promoting improved road transport outcomes

Guide to Traffic Management
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Summary

The Austroads *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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Guide to Traffic Management
Part 13: Road Environment Safety

Austroads

Sydney 2009

Austroads profile

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

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

Austroads membership

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

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

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

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1 INTRODUCTION

1.1 Scope

Part 13 of the Austroads *Guide to Traffic Management* has the title Road Environment Safety to define the limitations on 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.

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	Broader issues and aspects of managing networks of roads to provide effective traffic management for all road users Network needs of freight, public transport, pedestrians, cyclists and private motor vehicles Network management objectives, operational objectives, network performance measures.
Part 5	Road Management	Focus on managing mid-block traffic conditions Good practice for access management, allocation of space to various road users, lane management Application of speed limits.
Part 6	Intersections, Interchanges and Crossings	Types of intersection Selection of intersection type and appropriate use Traffic considerations in traffic management for intersections, interchanges and other crossings.
Part 7	Traffic Management in Activity Centres	Planning and traffic management of activity centres and associated transport nodes Principles for various types of centres.
Part 8	Local Area Traffic Management	Principles and processes Issues and resources Selection of schemes and treatments Design and implementation of schemes and devices.
Part 9	Traffic Operations	Applications used in traffic operations Current practice for common systems including: traffic signals, congestion management, incident management, traveller information Manual systems used in these application areas Event management Information management issues and principles 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 Data and surveys On-street and off-street Types of parking and parking control.
Part 12	Traffic Impacts of Developments	Relationship to road level of service and access management Development profile and trigger points for treatment Traffic impact assessment.
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 GRD (Guide to Road Design) and GRS (Guide to Road Safety).

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 roadside environment.

1.2 Context

Across Australia, approaches to improving road safety continue to be guided by 'Safe System' principles, which fundamentally involve making the road transport system more accommodating of human behaviour, while acting to minimise the contribution of that behaviour to road crashes (ATC 2008).

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.

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.

Much relevant information is available for achieving a safe road environment. In addition to the other Parts of the Guide to Traffic Management as listed in Table 1.1, guidance relevant to achieving a safe road environment is contained in several other Austroads Guides.

The primary cross references are the various Parts of the Guide to Road Safety and the Guide to Road Design. In the Guide to Road Safety some of the material referred to in the present document is treated in more detail and/or in a broader safety management context involving initiatives beyond those related directly to road and traffic management. Similarly, in the Guide to Road Design safety aspects are covered in the context of the design approaches and practices presented.

Part 13 of the Guide to Traffic Management 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. For the topics presented in Part 13, cross-references are given to their treatment in the relevant Parts of other primary Guides and in other Parts of the Guide to Traffic Management.

Table 1.2 summarises the primary safety-related sources within the relevant Austroads Guides.

Table 1.2: Austroads guidance on safe road environments

Austroads Guide	Parts relevant to road environment safety
Guide to Road Safety	Part 1: Road Safety Overview Part 2: Road Safety Strategy and Evaluation Part 3: Speed Limits and Speed Management Part 5: Safety for Rural and Remote Areas Part 6: Road Safety Audit Part 7: Road Network Crash Risk Assessment and Management Part 8: Treatment of Crash Locations Part 9: Roadside Hazard Management.
Guide to Road Design	Part 3: Geometric Design Part 4: Intersections and Crossings – General Part 4A: Unsignalised and Signalised Intersections Part 4B: Roundabouts Part 6: Roadside Design, Safety and Barriers Part 6A: Pedestrian and Cyclist Paths Part 6B: Roadside Environment (covers roadside furniture, road lighting, environmental aspects)
Guide to Pavement Technology	Part 3: Pavement Surfacings Part 7: Pavement Maintenance
Guide to Asset Management	Part 5: Pavement Performance (covers roughness, rutting, cracking, skid resistance)

The References list provides excellent background reading and guidance on achieving safer operation of the road environment.

1.3 Outline

This Part 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.

Part 13 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).

1.4 Purpose

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.

The primary focus of this Part is on traffic management and traffic engineering, but 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 authorities encourage a focussed approach to road safety engineering. This Guide will therefore also be a useful reference for senior managers in road authorities.

2 A SAFE ROAD ENVIRONMENT

2.1 Safe System Approach

The 'Safe System' approach has been espoused by the Australian National Road Safety strategy and by the separate state and territory road authorities. Details are given in the National Road Safety Action Plans (ATC 2008) and summarised in the *Guide to Road Safety, Parts 1, 2, 3 and 7* (Austroads 2006a, 2006b, 2006d, 2008a).

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.

Figure 2.1 illustrates the relationships between the basic elements of the road transport system under the Safe System concept.

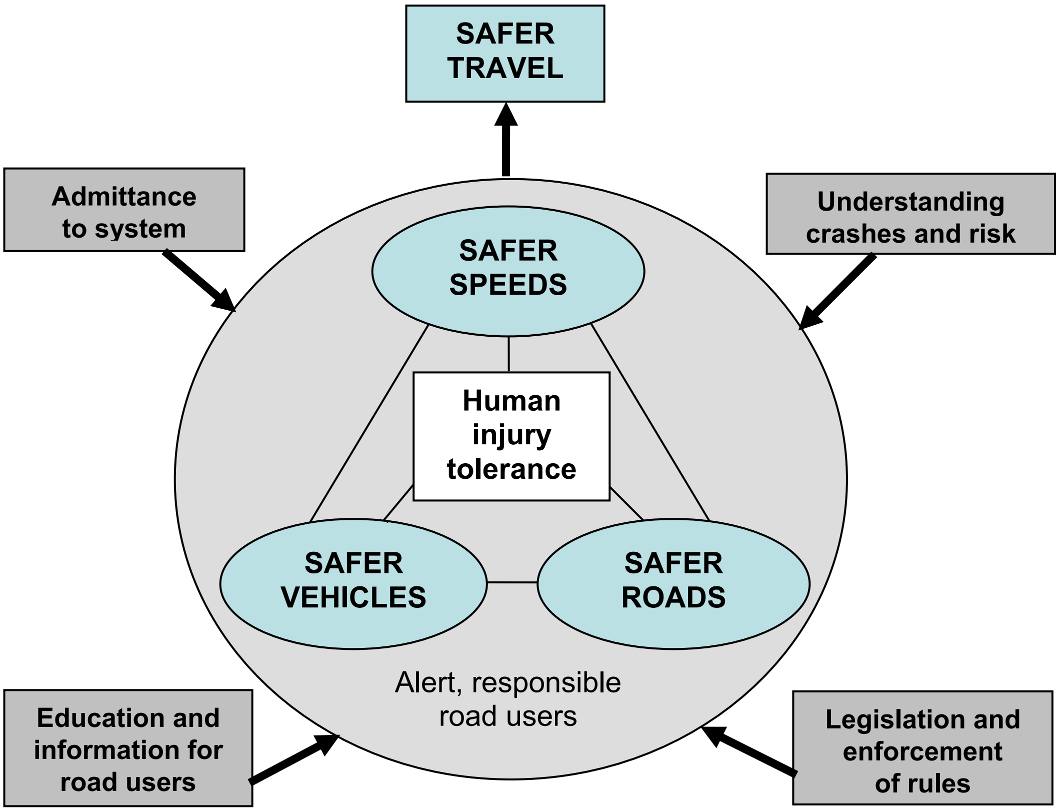


Figure 2.1: Conceptual overview of Safe System framework

The goal 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 approach aims to provide a safer road and traffic environment in which alert and responsible road users should not be killed or seriously injured as a result of a crash. It values the health and wellbeing of road users and takes human error into account while focusing on:

- safer roads and roadsides – good design of new roads and road furniture, identification and treatment of sites with adverse crash histories or inherent safety deficiencies, and good road management practices
- safer vehicles – vehicles which have improved functional design and protect occupants through structural design and protective equipment
- safer speed environment – speed limits which are appropriate for the road's function, construction, terrain and adjoining land use, so that speeds are contained within the limits of human injury tolerance.

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 it is designed and managed from a safety perspective, and that its operation is adequately monitored and measured.

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 'road'; that is, 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, 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, footpaths, etc.
- the devices placed on and adjacent to the road for managing the traffic it carries; for example, traffic signals, signs and markings, safety barriers, etc.
- the land use adjacent to the road, which generates traffic movements; for example, shopping centres, schools, residences, parks, mines, ports, etc.

The elements of a road environment are provided by:

- road authorities – 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, commercial lighting – which are extraneous to the road transport system and may cause visual clutter and distraction.

The last two points should be recognised and addressed by road authorities 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 the application of 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 minimise the number of mistakes made and the severity of their consequences.

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 also in terms of how those elements influence road user behaviour.

Guidelines for providing a safe road environment must take into account 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
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 contained
forgive	errant road user inappropriate behaviour or mistakes are forgiven, with the severity of consequences being contained
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 RTA (2006)

The *Guide to Road Safety, Part 8,* (Austroads 2009b) 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 the present document.

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 reducing 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, remedial countermeasure treatments and network risk assessment. An analytical and structured approach is required, involving application of the discipline known as road safety engineering.

3 HUMAN FACTORS AND THE ROAD SYSTEM

3.1 Introduction

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 three 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 have an understanding of the basic characteristics of human behaviour in the context of road users.

3.1.1 Human Factors

The term 'human factors' is 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 and McCormick 1992)

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-Machine-Environment Systems

3.2.1 Concepts

A fundamental concept is to consider the human operator as an element in an interacting human-machine-environment (H-M-E) system. The human operator in such a system acts in response to signals, or stimuli, from the environment and the machinery. This may be described by the basic psychological model of an 'input-stimulus-decision-response-output' mechanism. 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 – commonly referred to as human error.

3.2.2 Human Error

A general definition of human error, in the context of the H-M-E system, is 'an inappropriate or missing response'. Such errors may arise from:

- 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 human operator 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 operator'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, so as to avoid human error.

3.2.3 Application

The basic H-M-E system can be extended and applied to the road user situation. It is most commonly described in terms of the driver, but the concept is equally applicable to all road users, including motorcyclists, cyclists, and pedestrians. The road user does not operate in isolation, but as an element interacting with the vehicle and the road environment.

3.3 The Driver-Vehicle-Road System

3.3.1 Basic Model

The basic conceptual model of the Driver-Vehicle-Road (D-V-R) system recognises that the driver receives and processes inputs from the operating environment (the road and the vehicle), makes predictions and decisions about appropriate actions, executes those actions via the vehicle, and receives 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:

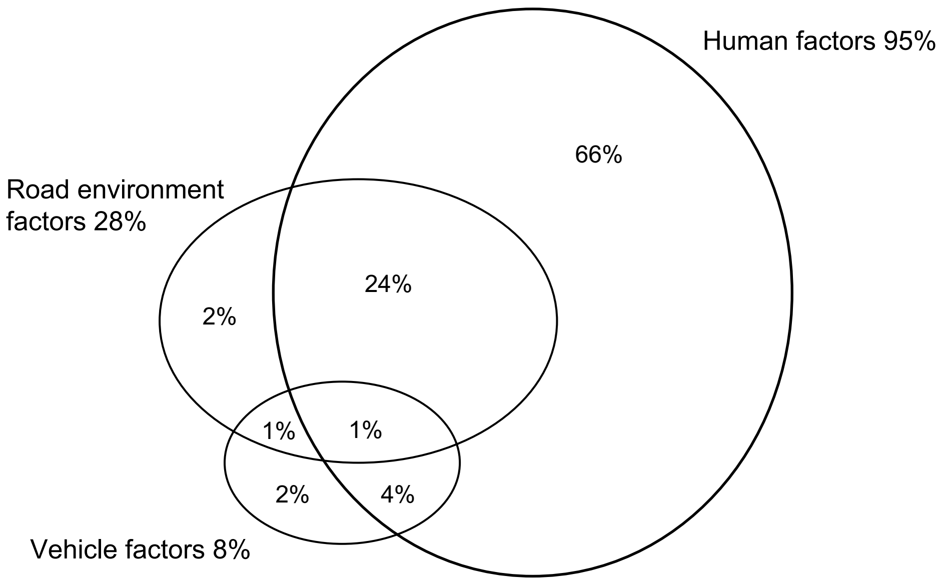
- inadequate or insufficient inputs (missed stimuli), e.g. night driving, poor sight distances
- driver difficulty in handling extreme inputs or uncommon events (unexpected stimuli), e.g. gravel or wet roads
- inadequate sampling or slow processing of inputs (insufficient time to process), e.g. because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

3.3.2 Human Factors in Crashes

The relative crash contributions of human, vehicle and road environment factors have been demonstrated in research studies involving in-depth investigations of many crashes. The results may be summarised as shown in Figure 3.1, based on information presented in Ogden (1996).

This illustrates that in approximately 95% of cases, human factors could be identified as major contributors. The corresponding figure for road environment factors is approximately 28%; and in most of those cases a combination of human and road environmental characteristics forms a major contribution.

This is not to suggest that behavioural factors are the main area for application of safety measures. Engineering measures in the road environment often have the greatest effect. A systematic approach must go beyond influencing the component factors and concentrate on measures that can accommodate the wider range of road user behavioural characteristics.



Source: adapted from Ogden (1996)

Figure 3.1: Factors contributing to crashes

This interaction of human and road factors suggests that road environment and traffic engineering measures can address crashes arising from factors other than just the road environment. Development of appropriate road environment safety measures must therefore be based on awareness of the crash involvement of particular characteristics of the road traffic environment, and an understanding of basic behavioural factors and road user responses in that environment. This relationship between road factors and human factors is well illustrated in the guideline produced by the World Road Association (PIARC 2007).

Under the Safe System approach, attention must be given to ensuring that all components – roads, vehicles, and road users – are managed to achieve safety gains. With regard to the physical environment, it is the responsibility of road designers and managers to ensure that the road environment is safe. The traffic engineer must be aware of the human factors contribution and acknowledge that traffic management initiatives and treatments operate through influencing human behaviour.

3.3.3 Driver Errors and System Design

The crash contribution from human factors must be examined in the context of driver errors.

The human error often identified in crash causation studies is frequently related to 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 so as 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.

3.3.4 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 in human behaviour into standards and guidelines.

The standards must be met, and application of guidelines provides 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 specifically 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 a number of parameters. 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 place. A combination of minimum standards may effectively result in a substandard design, and should be avoided.

As a further example, road users can be warned and informed of road features ahead by the use of appropriate signs and markings as prescribed in the relevant standards and guidelines. However, simple rote application is not sufficient. The designer of a layout of signs and markings will know what is intended; the approaching road user might not. The layout of the signs and markings should reliably deliver the intended message, and needs to be checked from the perspective of the naïve approaching road user 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.

3.4 The Driving Task

The driving task can be subdivided into tasks of 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 those 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; and involves physical activity in giving effect to those actions. Performance at 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.

A more extensive description of the driving task, and related behavioural characteristics, is given in Ogden (1996) and reflected in the *Guide to Road Safety, Part 8,* (Austroads 2009b). The main features are summarised in Section 3.5.

3.5 Driver Characteristics and Behaviour

3.5.1 Driver Behaviour Aspects

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, emotional stress).

Psychological traits can influence driver behaviour and therefore the operation of the D-V-R system. The driver brings to the task various values, norms, attitudes, motives and expectations based on 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 particular piece of information. In designing a road section or traffic management treatment, the capabilities and limitations of the users need to be considered; otherwise, demand placed on the users could be too great, leading to driver error.

3.5.2 Capabilities and Limitations

The driver's ability to receive and process information is influenced and limited by factors such as:

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 design of the road, and traffic management devices, meets these visual needs. Further discussion of road user visual characteristics and needs is given in the *Guide to Road Safety*, *Part 8* (Austroads 2009b) and, in the context of road lighting, the Guide to Road Design, Part 6B (Austroads forthcoming 2009i).

Perception and reaction times (PRT)

The perception and reaction time is the time consumed by a road user between stimulus and decision, between decision and action. Perception and reaction times are typically considered to range between 0.75 seconds and 2.5 seconds, but with a large variance. Some authors consider the range to be 0.5 to 3.5 seconds (Olsen, in Dewar and 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 and 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 and English, 1995) or detection, identification, decision and response Dewar and Olsen 2007 (Olsen 1996). 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 lead to driver error or loss of control, as summarised in Table 3.1.

Table 3.1: 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	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 or complex	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.

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.

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 manner in which 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.

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).

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 (PRT and STM). This can accentuate the information loss experienced under high rates of task demand.

3.6 Managing the System

In managing the driver-vehicle-road system, practitioners should take account of the behavioural characteristics outlined above. The information-processing model 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
- 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, and variable speed limits to reduce speed differentials.

Road and traffic engineering practitioners are concerned primarily with the last two approaches in seeking to achieve a safe road environment through minimising the likelihood of crashes. 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 particular issue being addressed.

There are also implications for the role of future developments in vehicle and traffic management technology, e.g. advances in ITS relating to communication between vehicles and the road environment. Due account must be taken of the behaviour, capabilities and limitations of the human operator (the driver, rider or pedestrian) in the design and operation of such systems.

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, in the planning of new developments, in the design of new roads, in safety improvements for existing roads, in remedial treatments of hazardous locations, in routine maintenance programs and in 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 the application of traffic and road engineering practices with the aim of preventing crashes and managing risk to an acceptable level. It also gives effect to the philosophy that one should aim to provide a road network or system which does not kill or unduly injure the users of the system.

A more developed definition can be adopted as follows:

> Applying the principles of road and traffic engineering, based on a sound analysis of all relevant data, with an understanding of road user behaviour, to identify and implement improvements to bring about cost-effective reductions in crashes and casualties. (Croft 2005)

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, 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, related surveys of specific issues
- analytical techniques – risk assessment, crash rates analysis, economic analysis, countermeasure evaluation studies, crash prediction modelling, target setting.

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, taking into account the needs of a range of road users. A broad objective is to provide acceptable 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. 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 traditional conceptual model for describing and analysing crashes is provided by the Haddon matrix (Table 4.1). It has two main variables – crash phase and system component. There are three crash phases (before, during, and after) and three system components (road users, vehicles, and road environment). Table 4.1 illustrates the basic matrix in which each cell provides an opportunity to identify typical factors in the analysis of crashes and their outcomes.

Table 4.1: Basic Haddon matrix

System component	Crash phase		
	Before crash	**During crash**	**After crash**
Road user	Training, education, attitudes, alertness, rule compliance	Protective equipment use – seat belts, helmets	Emergency medical services
Vehicle	Primary safety – brakes, roadworthiness, visibility	Secondary safety – occupant protection	Communication devices – phones, on-board signals
Road environment	Road geometry, delineation, surface condition, visibility	Roadside hazards – poles, trees, barriers	Median breaks, traversable shoulders, batters

Further discussion on the origins and role of the Haddon Matrix model in crash analysis and treatments is provided in the *Guide to Road Safety, Parts 1, 2, 7, and 8* (Austroads 2006a, 2006b, 2006d, 2009b).

From the road safety engineering perspective, the road environment factors can be further categorised according to whether they primarily affect exposure to crash risk, probability of crash occurrence, or severity of crash (Table 4.2).

Table 4.2: Primary effects of road environment factors

System component		Crash phase		
		Before crash	**During crash**	**After crash**
Road environment	Affecting exposure	Road network factors (traffic volume, road type, travel time)		Road engineering factors (shoulder width, median barriers) Roadside factors (emergency bays, telephones) Traffic system factors (motorist information/warning devices)
	Affecting probability	Road engineering factors (alignment, grade, shoulders, pavement, drainage) Traffic engineering factors (delineation, signs, signals, markings, speed limits, sight distances, gaps) Land use factors (land use type, traffic generation activity, rest areas) External factors (day/night, weather, sun glare)		
	Affecting severity		Roadside factors (trees, poles, culverts, bridges, fences, posts, barriers, embankments) Traffic engineering factors (speed limiting devices, speed limits)	

Source: adapted from RTA (2006)

Road safety engineering applies road and traffic engineering principles to address crash factors in the **before**, **during** and **after** phases of the road environment component of the matrix. It also has implications for the **before** phase of the road user component of the matrix. Application of road and traffic engineering principles to this component of the matrix recognises that issues of speed selection, and driver perception and reaction are strongly influenced by the road environment in which the road user operates.

The matrix also provides opportunities to identify countermeasures to crashes. A crash factor in one cell of the matrix can be addressed by application of a countermeasure from another cell. This acknowledges that crashes are almost always multi-factor events, and that crash factors interact with each other.

4.3.2 Documented Guidance

There is a range of documents which provide information and guidance relating to road safety engineering. Practitioners have a responsibility to operate within these requirements, and should make reference to such documents in seeking to achieve a consistent road environment. These documents include:

- legislation – mandatory legal requirements – rules – 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 safety effectiveness of 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 on the basis of research results, technological developments and innovation.

A road authority 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.

Nevertheless, 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 in close proximity to 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, behaviour modification, injury control or post-injury management (Ogden 1996). Road safety engineering is aimed primarily at crash prevention and, to some extent, behaviour modification and injury control.

Central to 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

Risk management is addressed in Australian/NZ Standard AS/NZS 4360 – 2004 Risk Management which presents broad, generalised guidance on managing risk. The *Guide to Road Safety, Part 7,* (Austroads 2006d) presents the principles and processes for assessing and managing the risk of crashes in road networks.

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 (Viner and English 1995, Viner and Schnerring 1994). It 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 a particular 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 – vehicles of many different types, 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 is defined as the point when control is lost of the potential damaging properties of the energy source (in the case of road transport, the kinetic energy of the vehicle).

This definition allows the inclusion of situations where a driver initially loses control 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. Latitude 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 (with the two moving vehicles on a constant-bearing collision course). The definition allows for the possibility that control could be regained, by swerving or braking, leading to a null outcome.

Risk can be defined by three elements:

- *Exposure:* The number of vehicles or people travelling past or through a particular point on the road; typically the traffic volume.
- *Probability:* The likelihood that anyone at any time or point on a road initially loses control.
- *Outcome:* An array of possibilities arising from an initial loss of control; can range from a null outcome where a driver regains control to serious injury or death outcomes.

Risk can be expressed as a function of the product of these three elements, namely:

Risk = f (Exposure x Probability x Outcome)

A safer road environment (one with a lower risk) can be achieved by reducing the exposure and/or the probability and/or the severity of any crash outcome. If the outcome is expressed in terms of crash types (for which cost data are available), risk can be expressed in terms of cost.

While a reduction in risk can generally be realised from reduced exposure, it is to be noted that this can be offset by road user expectancy issues arising from circumstances in which probability of conflict is low – for example, at rural rail crossings.

Viner (1991) refers to the concept of the energy damage model in risk engineering – the concept that energy exchange can cause damage – and refers to basic measures to control risk. Table 4.3 outlines these measures and indicates their application in the road and traffic environment.

Table 4.3: Application of risk control measures

Basic risk control measures	Application to road/traffic environment
Control the existence or amount of energy	Managing speed – reducing speeds to levels where crashes are less likely and injuries are less severe
Maintain the reliability of the hazard control mechanism	Maintaining control – ensuring drivers remain on their chosen path and in control of the direction and speed of their vehicle
Remove or reduce the need for the space transfer mechanism	Imposing some control to lessen the probability that potentially conflicting road users will enter into direct conflict
Raise the damage threshold of the recipient	Protecting road users by energy absorbing devices in vehicles or the road environment so they are less exposed to life-threatening injury
Separate the hazard and the recipient	Physically separating road users in the road environment so that they do not enter into direct conflict

Source: Viner (1991)

In 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 by ensuring that they remain in control of their energy source. 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' controllers (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 Managing Speed

The greater the energy, the greater the potential for damage. In the context of a safe road environment, this measure can be considered as guiding and controlling road users in terms of the amount of kinetic energy they provide or produce. Since the mass of a vehicle remains largely unchanged (apart from loads) and kinetic energy is related to the square of the velocity, controlling speed has a substantial impact on the amount of energy present.

Speed management is a critical factor in limiting the risk of crashes and the impact energy of crashes. Casualty crash risk rises exponentially with speed, so relatively small reductions in the higher speeds can realise substantial energy reductions and significant safety gains. These arise from both a reduced risk of crashing and from reduced severity of crashes which do occur.

There are limits to the forces humans can withstand in a crash, and limits to the physical energy that can be absorbed by protective systems, such as vehicle structures, seat belts, air bags, helmets, and safety barriers.

Applying speed limits is a basic tool in managing speed. Controlling speed is not simply provision of appropriate speed zones, but also the provision of a road environment that naturally elicits an appropriate speed response. For example, long wide straight local streets lead to higher speeds. Streets suitably altered by 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.

While it is a prime objective that the road environment should suggest the appropriate speed limit, it is often the case that speed limits can differ on roads of similar appearance because of crash history.

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 energy source (kinetic energy of the vehicle) is the driver. The use of the term 'controller' implies that control of the energy source can be more than the driver; it can also be by way of external controls, such as intelligent vehicle highway systems.

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 is able to recover control and continue on the 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 supply; they provide less friction at a point where a driver might be requiring more.

4.4.3 Separating Conflicting Elements

In the context of a road transport system, 'reducing the space transfer mechanism' means imposing some control to lessen the probability that potentially conflicting road users will enter into direct conflict. 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 occupy different parts of the road. Cars, trucks 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.

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 – the car would need to travel out of its lane to damage the bicycle rider. 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 car does not stop at a red signal, then 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.

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 limited 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 sign posts, 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 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.

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, 2006d, 2008b, 2009a, 2009b). From the 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.

4.5.1 Ensuring Safety in Planning and Design

The essential concept in this approach is the prevention of safety deficiencies through 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.

The *Guide to Road Safety, Part 6* (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 forthcoming 2009j, forthcoming 2009m).

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) will be the result. 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.

4.5.2 Treating Known Hazardous Locations

The essential concept in this approach is the specific treatment of deficiencies at locations with undue crash experience.

The basic technique is that of using specific remedial countermeasure treatments which address the particular 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 2009b).

4.5.3 *Identifying Safety Deficiencies in the Road Network*

The essential concept in this approach is strategic monitoring of the road network with regard to safety performance and potential.

The basic procedure is to implement a safety assessment system to measure and analyse the demonstrable and intrinsic safety aspects of the road network.

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.

The use and condition of a road changes over time. The adjacent land use can also change, generating 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.

Unlike crash investigation procedures, the road safety review 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).

Approaches measuring actual safety performance and assessing the relative risks of sections of the road network, leading to the setting of priorities for remedial treatment, may also be used. This approach is presented in detail in the *Guide to Road Safety, Part 7* (Austroads 2006d). A deficiency database and prioritisation process may be established (see for example Land Transport NZ 2006) by means of which safety deficiencies on a road network may be sorted in order of relative risk and programmed for remedial treatment.

Programs for safety assessment of road networks have been developed in which safety review processes and crash rate analyses are combined. The review components of such programs typically involve examination of the road infrastructure and its assessment in terms of safety potential, often with the production of safety performance scores.

These programs are often titled road assessment programs (RAP); they are well established in several European countries (EuroRAP), in Australia (AusRAP), New Zealand (KiwiRAP), the USA (USRAP), and are now being developed on an international basis (iRAP).

4.6 Safety Management Systems

Much is known about applying safety principles (e.g. speed management, conflict reduction, hazard management, road user information management) in road design, traffic management, and remedial treatment, and about the effectiveness of proven countermeasures. The issue is not what to do, but rather how to ensure that this is put effectively into practice on a continuous basis.

This has implications for the actions of road safety engineers in ensuring that the road network is designed and treated from a safety perspective, in pursuit of the Safe System approach. 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 authorities 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 Land Transport NZ, 2006). This approach generally requires that the following steps and processes be adopted:

- a strategic road safety direction and vision for the authority, including the stakeholder partnerships needed to develop it, and a strategic plan for achieving reductions in the crash situation from road and traffic management initiatives
- 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 authority 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 2006d).

For a successful road safety engineering management program within a road authority, it is important for all these components to be adequately developed and operating. Ideally, documentation of the safety management system should include a manual giving guidance to practitioners on developing, implementing and monitoring the program, and include practical examples.

As national road safety strategies seek to give effect to the Safe System approach, placing greater emphasis on realising safety gains from improvements to the road environment, the development and implementation of safety management systems becomes a more important context for road safety engineering.

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.

Fundamental principles for managing safety in road design, traffic management, and remedial treatment practice include:

- speed management (aiming to limit kinetic energy in the road traffic system, so that crashes are less likely due to longer decision-response distances, and human injury tolerances are not exceeded when crashes occur)
- conflict management (aiming to control manoeuvres at locations such as intersections, or where pedestrians are prevalent, to avoid conflicts and reduce crash risk)
- hazard management (removing or treating hazardous obstacles in the road environment so that injuries from crashes are contained within survivable limits or crashes are less likely due to greater recovery space)
- road user information management (ensuring an adequate, clear and timely release of information through signals, signs and markings to guide road user decisions and behaviour).

Pursuit of these principles is reflected in the various parts of the Guides to Traffic Management, Road Safety and 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.

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, superelevation) Pavement (friction, roughness, rutting)
Roadside	Natural features (terrain, watercourses, trees) Introduced features (cuttings, embankments, culverts, drainage pits, poles, barriers, pathways, cycleways)
Intersections	At-grade, grade-separated interchanges, rail crossings
Traffic facilities	Traffic controls (speed limits, traffic signals, marked crossings, medians, kerb extensions, humps) Intersection control (roundabouts) Signs (regulatory, warning, information) Markings (longitudinal and transverse lines, arrows, numerals) Delineation (lines, guideposts, reflectors)
Road lighting	Route lighting (routes, intersections, tunnels) Local street and pathway lighting

Australian and New Zealand Standards, and Austroads guidelines – particularly those noted in Section 1.2 – have been developed to guide practitioners in designing, constructing, installing, and maintaining these elements of the road network.

The text 'Safer Roads: A Guide to Road Safety Engineering' (Ogden 1996) provides detailed advice on the role of these engineering elements in achieving a safe road environment. It is essential background reading for road safety engineers.

A comprehensive review, from a research perspective, of the effectiveness of many road design and traffic management treatments in improving safety is given in Elvik and Vaa (2004).

The relationship between the basic elements of the road environment and the characteristics of a safe road environment (Section 2.2) are presented in Table A 1 (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

5.2.1 Road Alignment

The alignment of a road, in particular 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.

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 2009c) provides guidance for appropriate geometric design.

5.2.2 Cross-section

Cross-section width is relevant to providing a forgiving road environment. Wider lanes provide more space for avoiding minor tracking errors which can lead to crossing the centreline or running off the road.

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 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.

The Guide to Road Design, Part 3 (Austroads forthcoming 2009c) provides guidance for appropriate road cross-sections.

5.2.3 Pavement Features

Vehicles require friction to maintain speed on grades or curves, or to reduce speed on approaches to traffic controls. If a horizontal curve is combined with a steep grade, then there will be a lateral friction demand for negotiating the curve and a longitudinal friction demand for maintaining speed on the up grade. Automatic transmissions (whether in cruise control or not) often ‘kick down’ on uphill grades, leading to an increased friction demand from the transmission attempting to accelerate. If the friction supply drops to a low level in such situations, drivers can inadvertently demand more friction than the pavement can supply, leading to loss of control.

Pavement friction can be reduced by factors such as the polishing of pavement surfaces and in wet conditions. 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.

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 2006-2009a) allows pavement friction and smoothness to be maintained at an appropriately safe and forgiving level.

5.2.4 Roadsides

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 forgive road users of any errors or loss of control.

A basic concept in roadside management is the 'clear zone'. This is an area adjacent to the traffic lane that should be kept free of features that are potentially hazardous to errant vehicles. Any objects within the clear zone should be frangible or shielded by barriers.

The *Guide to Road Safety*, *Part 9* (Austroads 2008b) and the Guide to Road Design, Parts 6 and 6B (Austroads forthcoming 2009g, forthcoming 2009i) 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, trees) and man-made objects (such as utility poles, culvert headwalls, bridge end abutments) but also traffic management devices installed within the roadway – such as traffic signal posts, sign posts, lighting columns and safety barriers in gore areas. Detailed guidance on the treatment of these objects in response to crash involvement is also given in the *Guide to Road Safety, Part 8* (Austroads 2009b).

The *Guide to Road Safety, Part 5* (Austroads 2006c) 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.

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), whether they need to turn as appropriate for their journey (guidance) and when they should proceed (control).

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

Achieving a safe road environment requires careful consideration of the location of intersections in relation to the road geometry and in relation to each other, so that appropriate layouts are provided and appropriate 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 forthcoming 2009d) 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 problems of one intersection being overlooked by drivers, even when traffic signals are installed, or drivers being overloaded by too much information. Freeway interchanges located too close together can lead to unsafe weave 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 particular 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.

Particular 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.

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 crashes between through and right-turning vehicles. 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.

The Guide to Road Design, Part 4 (Austroads forthcoming 2009d) and the *Guide to Traffic Management*, *Part 6* (Austroads 2007b) provide guidance to the appropriate design, layout and traffic management of intersections. 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.

5.2.6 Traffic Controls

Traffic controls in this context are of two main types – regulatory, such as road rules relating to speed limits and road user behaviour, and physical devices seeking to directly influence the passage of vehicles.

Speed management is fundamental to the safe management of traffic. Guidance on the principles and practice of speed management, with particular 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 2008c).

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 local traffic areas. They need to be clearly evident in the road environment by reason of their placement and appearance (contrasting colours, materials). Additional devices such as signs, kerb painting and linemarking may be necessary. 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 2008d) and Guide to Traffic Management, Part 10 (Austroads forthcoming 2009l).

Consistency of treatment along a route is important in obtaining correct road user responses. This can arise in 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 specific 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

Traffic signals are designed and installed for traffic efficiency purposes or road safety purposes. The primary role is to separate, by temporal control, road user movements that are potentially in conflict.

Signal phase settings (for example, regarding protected turn arrow movements) for intersection capacity management might need to be adjusted to ensure that driver expectancies are met and safe behaviour is followed.

Simply installing signals in response to a broadly stated ‘safety problem’ at an intersection might not address the specific nature of 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 2009b).

The *Guide to Traffic Management, Part 6* (Austroads 2007b) provides detailed guidance on the application of traffic signals to intersection control, and the Guide to Traffic Management, Part 10 (Austroads forthcoming 2009l) 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 forthcoming 2009k).

5.2.8 Traffic Signs

Signs are used to warn and inform road users of the roadway ahead, and to guide and control road users through complex and unusual situations.

Standards and guidelines such as the Australian Standard AS 1742 series: Manual of Uniform Traffic Control Devices, and the New Zealand Manual of Traffic Signs and Markings,(Transit New Zealand 2007) prescribe signing practices – in terms of hierarchy, shape, colour, size, legibility and placement.

Note: in New Zealand, requirements similar to those set out in Australian Standard AS 1742 are contained in Land Transport Rules: Traffic Control Devices Rule (2004), Road User Rule (2004) and Speed Limits Rule (2003). www.landtransport.govt.nz/rules

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 absolutely necessary, and the use of alternative symbols should be approved only after rigorous testing in accordance with AS2342. (Standards Australia 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 forthcoming 2009l) provides guidance to the appropriate use of signs and markings. The *Guide to Traffic Management, Part 8* (Austroads 2008d) also provides similar guidance specifically for local area traffic management schemes.

5.2.9 Markings and Delineation

Road markings provide information, guidance, and control, through lines and symbols (numerical or other characters). Delineating the road alignment ahead provides important driver guidance, by means of linemarking and signs. This allows road users to determine the way ahead (long range delineation) and to position the vehicle laterally on the road (short range delineation).

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

Incorrect or poorly maintained pavement marking 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 driver error.

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 linemarking 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 linemarking 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 forthcoming 2009l) provides guidance on the form and placement of pavement linemarking and associated delineation devices.

5.2.10 Road Lighting

Road lighting is an integral part of traffic engineering practice, aiming to make the road environment and objects in it sufficiently visible to ensure that the driving task is performed safely. It assists in informing road users of the road layout and traffic controls ahead.

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

Lighting arrangements include route lighting along urban and some semi-rural roadways, assisting delineation of the road ahead, and 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 forthcoming 2009i).

5.2.11 Roadworks

Traffic control and management at roadworks is an essential component of network safety management. The immediate environment of roadworks sites needs to meet the basic safety characteristics of providing warning, information, guidance, and control for 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 sites.

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 sites 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 linemarking
- barrier types and deployment
- pedestrian and roadworker facilities
- inactive 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 authority should have a clear strategy and procedures for managing safety at roadworks sites. 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 (Standards Australia 2002) and the New Zealand Code of Practice for Temporary Traffic Management (Transit NZ 2004).

<u>Note</u>: in New Zealand, requirements similar to those set out in Australian Standard AS 1742 are contained in Land Transport Rules: Traffic Control Devices Rule (2004), Road User Rule (2004) and Speed Limits Rule (2003). www.landtransport.govt.nz/rules

REFERENCES

Australian Transport Council 2008, *National* Road *Safety Action Plan 2009-2010*, ATC, Canberra, ACT.

Austroads 2006-2009a, *Guide to Asset Management,* Austroads, Sydney, NSW

Austroads 2006-2009b, *Guide to Road Design, Parts 1-8,* Austroads, Sydney, NSW.

Austroads 2006-2009c`, *Guide to Road Safety, Parts 1-9,* Austroads, Sydney, NSW.

Austroads 2006a, *Guide to Road Safety: Part 1: Road Safety Overview*, AGRS01/06, Austroads, Sydney, NSW.

Austroads 2006b, *Guide to Road Safety: Part 2: Road Safety Strategy and Evaluation* AGRS02/06, Austroads, Sydney, NSW.

Austroads 2006c, *Guide to Road Safety: Part 5: Road Safety for Rural and Remote Areas*, AGRS05/06, Austroads, Sydney, NSW.

Austroads 2006d, *Guide to Road Safety: Part 7: Road Network Crash Risk Assessment and Management*, AGRS07/06, Austroads, Sydney, NSW.

Austroads 2007-2009, *Guide to Traffic Management, Parts 1-13,* Austroads, Sydney, NSW

Austroads 2007a, *Guide to Traffic Management: Part 1: Introduction to Traffic Management*, AGTM01/07, Austroads, Sydney, NSW.

Austroads 2007b, *Guide to Traffic Management: Part 6: Intersections, Interchanges and Crossings,* AGTM06/07, 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 2008c, *Guide to Traffic Management: Part 5: Road Management*, AGTM05/08, Austroads, Sydney, NSW.

Austroads 2008d, *Guide to Traffic Management: Part 8: Local Area Traffic Management*, AGTM08/08, Austroads, Sydney, NSW.

Austroads 2009a*, Guide to Road Safety: Part 6: Road Safety Audit,* AGRS06/09, Austroads, Sydney, NSW.

Austroads 2009b, *Guide to Road Safety: Part 8: Treatment of Crash Locations*, AGRS08/09, Austroads, Sydney, NSW.

Austroads forthcoming 2009a, 'Guide to Pavement Technology: Part 3: Pavement Surfacings', Austroads, Sydney, NSW.

Austroads forthcoming 2009b, 'Guide to Pavement Technology: Part 7: Pavement Maintenance ', Austroads, Sydney, NSW.

Austroads forthcoming 2009c, 'Guide to Road Design: Part 3: Geometric Design', Austroads, Sydney, NSW.

Austroads forthcoming 2009d, 'Guide to Road Design: Part 4: Intersections and Crossings: General', Austroads, Sydney, NSW

Austroads forthcoming 2009e, 'Guide to Road Design: Part 4a: Unsignalised and Signalised Intersections', Austroads, Sydney, NSW.

Austroads forthcoming 2009f, 'Guide to Road Design: Part 4b: Roundabouts', Austroads, Sydney, NSW.

Austroads forthcoming 2009g, 'Guide to Road Design: Part 6: Roadside Design, Safety and Barriers', Austroads, Sydney, NSW.

Austroads forthcoming 2009h 'Guide to Road Design: Part 6a: Pedestrian and Cyclists Paths', Austroads, Sydney, NSW.

Austroads forthcoming 2009i, 'Guide to Road Design: Part 6b: Roadside Environment', Austroads, Sydney, NSW.

Austroads forthcoming 2009j, 'Guide to Traffic Management: Part 7: Traffic Management in Activity Centres,' Austroads, Sydney, NSW.

Austroads forthcoming 2009k, 'Guide to Traffic Management: Part 9: Traffic Operations', Austroads, Sydney, NSW.

Austroads forthcoming 2009l, 'Guide to Traffic Management: Part 10: Traffic Control and Communication Devices,' Austroads, Sydney, NSW.

Austroads forthcoming 2009m, 'Guide to Traffic Management: Part 12: Traffic Impacts of Developments', 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, Tasmania, 23p.

Croft, PG 2005, 'Road safety engineering: a sustainable approach', *Institute of Transportation Engineers (ITE) Annual Meeting, 2005, Melbourne, Australia*, ITE, Washington, DC.

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

Elvik, R & Vaa, T (eds) 2004, *The handbook of road safety measures*, Elsevier, Oxford, United Kingdom

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

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

Land Transport New Zealand 2006, *Guidelines for developing and implementing a safety management system for road controlling authorities*, Land Transport New Zealand, Wellington, viewed 9 April 2009, www.landtransport.govt.nz/roads/sms/guidelines-dev-implement-sms.html

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

Olsen, P 1996, *Forensic aspects of driver perception and response*, Lawyers and Judges Publishing, Tucson, Arizona, USA.

PIARC 2007, 'Human factors guideline for safer road infrastructure: draft November 2007', World Road Association (PIARC), Paris.

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

Sanders, MS & McCormick, EJ 1992, *Human factors in engineering and design*, 7th edn, McGraw Hill, New York, USA

Transit NZ 2004. *Code of practice for temporary traffic management,* SP/M/010, Transit New Zealand, Wellington

Transit NZ 2007, MOTSAM *: manual of traffic signs and markings: part 1: traffic signs*, 4th edn, Transit New Zealand, Wellington, NZ

Viner, D 1991, *Accident analysis and risk control*, VRJ Delphi, Carlton South, Vic.

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

Viner, D & Schnerring, F 1994, 'Risk engineering models for road safety', *Australian Institute of Traffic Planning and Management (AITPM) national conference, 7th, 1994, Sydney, New South Wales*, AITPM, Sydney, NSW, 10p.

Australian / New Zealand Standards

AS 1742-1990-2007, *Manual of uniform traffic control devices (15 Parts*).

AS1742.3-2002, *Manual of uniform traffic control devices: part 3: traffic control devices for works on roads*.

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

AS/NZS 1158- Set 2007, *Lighting for roads and public spaces*.

AS/NZS 4360-2004, *Risk management*

APPENDIX A SAFE ROAD ENVIRONMENT ELEMENTS – STANDARDS AND GUIDELINES DIRECTORY

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 series	AS 1742 series	
Inform	**GRD Parts 1, 3**			**GRD Parts 1, 4, 4A, 4B**		AS 1742 series **GTM Parts 8, 10**	AS 1742 series **GTM Parts 8, 10**	AS 1158
Guide				**GRD Parts 4, 4A, 4B** **GTM Parts 6, 8**	AS 1742 series **GTM Parts 5, 8, 9, 10**	AS 1742 series **GTM Parts 8, 10**	AS 1742 series **GTM Parts 8, 10**	
Control		**GAM Part 5** **GPT Part 7**	**GTM Part 11**	**GTM Part 8**	**GTM Parts 5, 8, 9, 10** **GRS Part 3**	AS 1742 series **GTM Parts 8, 10**	AS 1742 series **GTM Parts 8, 10**	
Forgive	**GRD Part 6**		**GRD Part 6** **GRS Part 9**					
No surprise	**GRD Parts 1, 3**			**GRD Part 4** **GTM Part 6**				AS 1158
Controlled release		**GRD Part 4** **GTM Part 6**			AS 1742 series **GTM Parts 5, 8, 9, 10**	AS 1742 series **GTM Parts 8, 10**	AS 1742 series **GTM Parts 8, 10**	

Table A 1: Safe road environment elements - standards and guidelines directory (Continued)

Safe road environment features	Road environment elements							
	Road geometry	**Pavement**	**Roadside**	**Intersections**	**Traffic controls**	**Signs**	**Markings**	**Lighting**
Repeat information					AS 1742 series **GTM Parts 5, 8, 9, 10** **GRS Part 3**	AS 1742 series **GTM Parts 8, 10**	AS 1742 series **GTM Parts 8, 10**	
Meet expectations	**GRD Parts 1, 3**	**GRD Part 4** **GTM Part 6**			AS 1742 series **GTM Parts 5, 8, 9, 10** **GRS Part 3**	AS 1742 series **GTM Parts 8, 10**	AS 1742 series **GTM Parts 8, 10**	
Friction supply			**GAM Part 5** **GPT Part 7**					
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 1158 Australian Standard: Lighting for roads and public spaces