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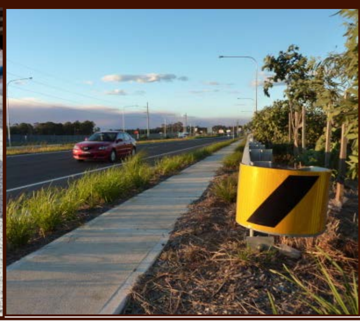
AUSTROADS RESEARCH REPORT

Asset Management within a Safe System


Austroads

Asset Management within a Safe System

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Project Manager

Tom Engelke, Main Roads Western Australia

Prepared by

Tyrone Toole, Julia Kelley and Blair Turner
ARRB Group

Published by Austroads Ltd
Level 9, Robell House
287 Elizabeth Street
Sydney NSW 2000 Australia
Phone: +61 2 9264 7088
Fax: +61 2 9264 1657
Email: austroads@austroads.com.au
www.austroads.com.au

Asset Management within a Safe System

Austroads
Sydney 2013

About Austroads

Austroads' purpose is to:

- promote improved Australian and New Zealand transport outcomes
- provide expert technical input to national policy development on road and road transport issues
- promote improved practice and capability by road agencies.
- promote consistency in road and road agency operations.

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

- Roads and Maritime Services New South Wales
- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department of Planning, Transport and Infrastructure South Australia
- Department of Infrastructure, Energy and Resources Tasmania
- Department of Transport Northern Territory
- Department of Territory and Municipal Services Australian Capital Territory
- Commonwealth Department of Infrastructure and Transport
- 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 transport sector.

SUMMARY

Project AT1692 was established by Austroads to consider the implications for asset management of the new Safe System approach and to help understand what implementing a Safe System would mean for asset managers. Both the Australian and New Zealand National Road Safety Strategies have adopted the Safe System, and there is a requirement for road agencies to take responsibility and act within their powers to minimise harm even in circumstances where they may not be negligent, through internal actions and cooperation with other stakeholders and the community.

This report addresses the above needs by introducing the background to and evolution of the Safe System, recognising the need to manage crash forces to minimise fatal and serious injury outcomes, and the range of infrastructure and road use management solutions which could help reduce road trauma. The solutions extend beyond traditional solutions, building on the Safe System philosophy and integrating these with asset maintenance and road safety practice.

The report identifies similarities between the Safe System and the Austroads Asset Management framework, and their underlying philosophies, with substantial opportunities for an integrated approach. These recognise core drivers, such as the respective National Road Safety Strategy, the need to manage parts of the network differently with a focus on risk management, incremental improvements and the opportunities afforded by new roads and major upgrades.

The role of data and evidence based analysis and program development is a major opportunity, and the forthcoming Australian National Risk Assessment Model (ANRAM) and New Zealand's KiwiRAP and other road agency guidelines and tools has the potential to make substantial contributions. The proposed ANRAM investment decision framework also provides a useful classification to aid the selection of appropriate strategies for different parts of the network. The need is to do more, and build on established practices in the interests of maximising harm reduction. This will require a balanced approach considering all outcome areas within the broader asset management imperative to maintain and preserve existing assets.

Key process requirements to aid the objective of Safe System within the asset management framework have been defined, with a focus on the strategic asset management phases one to four. These were chosen because there are greater opportunities within these phases to maximise beneficial outcomes. They also provide greater opportunity for integrated solutions, and a practical framework for action.

Examples of key knowledge are presented against the various asset management phases which illustrate the integration of asset management and the Safe System in response to the requirements and purpose of the proposed framework. They address the specific questions and issues which formed the basis for this project, and are accompanied by take home messages to aid their application in different contexts, e.g. maintenance and operations, brownfields and greenfields.

A number of cross-cutting issues which are relevant to a number of phases are assigned to the one most suited to their initial consideration, including such issues as legal implications, asset creep and whole-of-life-cycle costs.

The project has also identified knowledge gaps, including possible revisions to the Guide to Asset Management and other relevant guides to aid the achievement of a Safe System.

It is concluded that achieving the required progress will require a strategic whole-of-business style approach harnessing the capacity within different disciplines, and across different programs.

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1 INTRODUCTION

1.1 Background

The management of road assets under the asset management discipline is a well-established practice. It requires consideration of a broad range of factors to deliver outcomes of interest to road agencies and the community. It extends beyond the maintenance of existing assets and includes the creation of new assets, enhancement of in-service assets and asset disposal, and supports transport efficiency, route availability, the safety of road users and the protection of the environment and our cultural heritage. This is consistent with the Austroads *Guide to Asset Management* (GAM) (Austroads 2009), and its accompanying Integrated Asset Management (IAM) Framework, where asset managers are encouraged to utilise the full suite of physical and road use management solutions to deliver community outcomes at minimum cost.

Whilst asset managers may not have primary responsibility in decisions related to the provision of new or improved assets, there is a need for them to be involved to ensure provision is made for future maintenance. Arguably, at a strategic level, asset managers should have been involved in identifying a gap in the established road network.

The reality of strong competition for resources across sectors, which inevitably imposes funding constraints, and a strong desire by communities to maximise results in a number of outcome areas, means that trade-offs are required and ideal standards are rarely achieved. Consequently, there is a need to maximise benefits from available funding by being both technically efficient in delivering the performance sought, and through allocating funds to the most deserving parts of the network.

As managers are stewards of the road network, they have a responsibility to plan, take appropriate actions and to influence the actions of others to implement policy to help achieve outcomes.

The challenge of reducing the trauma arising from road crashes is an area where improved outcomes require a coordinated multidisciplinary and cross-agency approach. Road agencies around the world are adopting a Safe System approach to deliver road safety outcomes. Both the Australian (Australian Transport Council 2011) and New Zealand (Ministry of Transport 2010) National Road Safety Strategies (NRSS) are built upon adoption of a Safe System approach.

The Safe System is a targeted approach that ultimately aims to eliminate fatal and serious injury (FSI[1]) on the road. It recognises that motorists inevitably make errors in judgment that may lead to a crash and it is understood that there are limits to the force that the human body can withstand (without causing death or serious injury) in a crash. These limitations are directly linked to the type of crash and the speed of the impact. The Safe System approach aims to support development of a transport system better able to accommodate human error and road user vulnerability. This can be achieved through better management of crash energy, so that individual road users are not exposed to crash forces likely to result in death or serious injury.

A key strategy in achieving Safe System objectives is through road network improvements (safer infrastructure), and speed management. Speeds need to be managed in such a way as to match the level of protection offered by the road infrastructure and modern vehicle safety features.

[1] FSI, representing a Fatal or Serious Injury, is used throughout this report, whereas the acronym KSI representing killed or seriously injured is widely used and has the same meaning.

A move to the Safe System approach is accompanied by a fundamental shift in road safety thinking where it can no longer be assumed that the burden of road safety responsibility simply rests with the individual road user. Road agencies have a primary responsibility to provide a safe operating environment for road users. This is because they have a significant involvement in the management and subsequent performance of the road transport system, and the way roads and roadsides are used and to ensure that the system is forgiving when people make mistakes. Consequently, within the Safe System agencies should strive to eliminate serious and fatal crash consequences from their road networks. It is no longer acceptable to assume these crash types are beyond their control or influence even when driver error may be a significant cause contributor.

Traditionally, road safety considerations have been either embedded within the original design process or maintenance activities, with the latter focused on the physical deterioration or consumption of pavement and bridge assets, or have been addressed through safety improvement works at identified blackspots, or through the provision of new or upgraded, safer infrastructure.

Whilst useful, such strategies limit the scope for reducing fatal and serious crashes. To achieve Safe System outcomes within the timescales and to the extent sought by the NRSS and agency specific strategies, road agencies will need to change how they identify and respond to less forgiving features of existing as well as new infrastructure. Asset managers are seen as a key enabler and deliverer of this change. However, how road agency practices and infrastructure will change and respond to the Safe System vision needs to be more fully understood and defined, whilst maintaining a balance with other agency objectives.

1.2 Project Aim

Project AT1692 was established by Austroads to consider the implications for asset management within the new Safe System approach and to help understand what implementing a Safe System would mean for asset managers, with the following specific aims:

- to give early consideration to implications for asset management in the Safe System philosophy
- to provide advice to agencies about the need to consider the potential for the Safe System philosophy to drive a change in maintenance costs[2], prioritisation processes, Key Performance Indicators (KPIs) and targets, intervention levels and treatment selections.

In so doing, the project aims to understand the emerging issues in asset management associated with the Safe System approach and presents a summary of knowledge and case studies of current practice that underpin and demonstrate opportunities and barriers to the implementation and enhancement of the Safe System. As the Safe System has evolved from road safety the project considers the interactions of asset management and road safety, and other disciplines.

1.3 Method

To progress understanding of what asset management would look like within a Safe System framework and to demonstrate what changes to current practices might be required, current practices were examined through:

1. a review of literature jointly examining the Safe System and issues related to asset management
2. a survey of member agencies to determine an understanding of the emerging issues and gather data about likely impacts on asset management practice

[2] In the context of this report, the reference to costs has been interpreted as meaning those associated with the entire life cycle, including the creation of an asset, and the operation and improvement/enhancement of assets.

3 preparation of issues papers on the following range of topics of primary interest to the member agencies:

   (a) exploring what asset management within a Safe System means
   (b) safety implications of existing infrastructure – maintenance treatments and condition factors
   (c) network assessment with regard to Safe System – data, gap analysis and current status reporting
   (d) influence of Safe System on treatment selection and option analysis
   (e) optimisation and prioritisation under a Safe System
   (f) legal considerations for a Safe System
   (g) asset creep, meaning the increase in asset types and associated costs of ongoing maintenance and renewal, associated with adopting a Safe System

4 exploration of the above issues in a practitioners workshop, and identified areas of consensus, positives to act upon, challenges and knowledge gaps

5 further consultation, accumulation of illustrative case studies and the preparation of this final project report which describes the potential impact of the Safe System approach on asset managers at a strategic and operational level.

1.4 This Report

1.4.1 Purpose

The purpose of this final project report is as follows:

1 to provide specific guidance on what Safe System means in terms of asset management

2 to encourage consistency of terminology, thinking and approaches

3 to bed down asset management and Safe System interrelated concepts, encourage consistent language and provide a common foundation and an established minimum level of understanding for practitioners

4 to illustrate opportunities to integrate the Safe System approach within asset management through specific case studies

5 to offer recommendations and amendments to the current Austroads *Guide to Asset Management* (GAM), and other associated guidance, as a result of this work.

Finally, the report is intended to support discussion on how asset managers can fulfil their roles and responsibilities in a manner that complements and encourages implementation of a Safe System. The report has been written to enable conversations on what the adoption of a Safe System approach means for asset managers, and presents the consolidated project findings and conclusions.

1.4.2 Scope

Following this Introduction, the report is structured as follows:

- Section 2, *Emergence of the Safe System Approach*, provides background on the evolution and basis of the Safe System, and its differences and similarities with the traditional road safety approach. Examples of Safe System infrastructure are provided.

- Section 3, *Convergence of Asset Management and Safe System*, introduces the basic components of the Austroads asset management framework, and discusses how it provides a platform for delivering the Safe System vision in a pragmatic manner within asset management practice. It also introduces specific drivers such as the National Road Safety Strategy, the need to address different contexts, such as Brownfields, Greenfields, maintenance and operations, and the forthcoming Australian National Risk Assessment Model (ANRAM) each of which are important to the aim of integrating Safe System.
- Section 4, *Achieving Integration*, explains the use of the Austroads Integrated Asset Management framework as a basis for integrating the Safe System within asset management, and describes the specific requirements road agencies should meet to implement a Safe System.
- Section 5, *Safe System and Asset Management Integration: Applications and Examples*, addresses specific questions and issues and offers take home messages of relevance to asset managers and details specific case studies and best practice.
- Section 6, *Proposed amendments to the current Austroads guides*, contains a summary of recommended changes within the GAM, and other guides.
- Section 7, *Conclusions*, summarises the key findings, proposed research and development needs.

2 EMERGENCE OF THE SAFE SYSTEM APPROACH

2.1 The Safe System

The Safe System approach represents a significant change in the way that road safety is managed and delivered in Australasia. The approach recognises that humans, as road users, are fallible and will continue to make mistakes. In addition, humans are physically vulnerable, and are only able to withstand limited kinetic energy exchange (e.g. during the rapid deceleration associated with a crash) before serious injury or death occurs. Infrastructure is required that takes account of these errors and vulnerabilities so that road users are able to avoid serious injury or death in the event of a crash. Safe System principles aim to manage vehicles, road and roadside infrastructure, and speeds to eliminate death and serious injury as a consequence of a road crash.

The Safe System approach reflects a holistic view of the combined factors involved in road safety. A Safe System protects responsible road users from death and serious injury by taking human error and frailty into account, and has four essential elements:

- alert and compliant road users
- safe roads and roadsides
- safe speeds
- safe vehicles.

Management of speed is a core feature of the Safe System approach. Human tolerances need to be considered in the setting of speed limits so that, in the event of a crash, the chances of road users being killed or seriously injured are minimised. For example, in collisions between cars and pedestrians, the chance of survival decreases dramatically above speeds of **around** 30 km/h. Unless adequate infrastructure is provided (such as separation of cars and pedestrians), speeds need to be below this level to ensure survival in the event of a crash. Similar critical speeds exist for side collisions (e.g. at intersections) between cars (50 km/h) and head-on crashes (70 km/h). To prevent death or serious injury involving these crash types, infrastructure must be provided to minimise the chance of a crash, or the severity if a crash does occur, or the speed must be below these levels for car-pedestrian and car-car impacts. For collisions involving heavy vehicles and large stationary objects survival rates will be considerably lower, making the task of managing speeds and impact forces even more critical.

The Safe System approach is based primarily on the Swedish ‘Vision Zero’, and the Dutch ‘Sustainable Safety’ approaches. Vision Zero suggests that it is not acceptable for fatal or serious injuries to occur on the road system, and that account must be taken of human tolerances when designing road infrastructure (e.g. Tingvall 1998). The Sustainable Safety approach (Wegman & Aarts 2006) is based on the following concepts, the first four of which relate most directly to road infrastructure improvements and road use management:

- Functionality: roads should be differentiated by their function, with through roads which are designed for travel over long distances (typically at high speed, ideally on a motorway); distributor roads which serve districts, regions and suburbs; and local roads, which allow access to properties.
- Homogeneity: differences in vehicle speeds, direction of travel and mass on specific roads should be minimised.
- Predictability: the function and rules of a road should be clear to all road users. This approach has led to the development of the ‘self-explaining road’ (e.g. Schermers 1999, Theeuwes & Godthelp 1992).

- Forgivingness: roads and roadsides should be forgiving to road users in the event of an error.
- State awareness: road users should be able to assess their capability of handling the driving task.

2.2 Safe System Infrastructure, Road Use Management and CITS

Key Safe System components for asset managers are forgiving infrastructure and speed management. Safer vehicles are also relevant as they relate to infrastructure and speed.

2.2.1 Framework for Infrastructure Solutions

Turner et al. (2009) presents a framework for Safe System infrastructure solutions based on key crash types (Table 2.1). Safe System infrastructure/treatments are considered to be those that have the potential to deliver near zero death and serious injury (termed **Primary treatments** in Turner et al. 2009).

Table 2.1: Safe System infrastructure

Crash type	Example Safe System treatments	Issues
Run-off-road	Centre and edge barrier systems – particularly wire-rope barriers which offer a greater degree of deflection, thereby absorbing energy and redirecting vehicles back into their lane	▪ Wire-rope barriers are less able to contain heavy vehicles. ▪ Most barrier systems pose risks for vulnerable road users. ▪ Barrier systems (this includes terminals and transitions) are still a hazard – some deaths and injuries still occur. ▪ Depending on type there may be Safe System implications for workers during maintenance activities.
	Clear zones	▪ Crashworthy roadside furniture may be present within the clear zone, although this may still present a risk to motorcyclists. ▪ Significant crash reductions possible with moderate clear zone widths (> 4 m) but need to be very wide to minimise harm.
Intersection	Grade separation	▪ Costly.
	Roundabouts	▪ Need to be well designed with adequate deflection on approach. ▪ Concerns regarding vulnerable road users. ▪ Some issues with heavy vehicles (e.g. gap acceptance for road trains).
	Intersection platforms	▪ Suitable in lower speed environments, as they reduce speeds to 50 km/h or less. Relatively untested in Australian and New Zealand conditions, but used widely in parts of Europe.
Head-on	Median barriers	▪ Depending on type there may be Safe System implications for workers during maintenance activities. ▪ Has to be appropriate type depending on vehicle usage and width considerations.
Pedestrian	Grade separation	▪ There is often low utilisation of this treatment due to inconvenience to pedestrians.
	Raised pedestrian crossings (wombat crossings) and other relevant traffic calming	▪ Suited to lower speed environments, or key locations on higher volume routes.

Note: Speed management is a relevant treatment consideration for all these crash types and is discussed in more detail in Section 2.2.2.

Source: Adapted from Turner et al. (2009).

However, in some cases, no primary treatments exist, and the nearest relevant treatment is presented. In many cases these treatments require further design and refinement in order to provide Safe System outcomes. In other cases it is expected that vehicle design and technologies will be required to produce these benefits. Other safety treatments (termed **Supporting treatments** in Turner et al. 2009) are available for each of these crash types. However, whilst they reduce the likelihood of a crash, they do not fully reduce the consequence, and therefore do not conclusively eliminate FSI outcomes. They are, however, expected to improve safety and be practical and physically able to be installed and maintained. For instance, the use of audio-tactile edge lines reduces run-off-road crashes, but does not eliminate them. They are also likely to reduce collisions with roadside barriers thereby reducing maintenance requirements.

Notwithstanding the distinction between primary and supporting treatments, supporting treatments have an important role to play in minimising harm, have been widely used in the past decade and are useful tools in an incremental approach to crash reduction.

2.2.2 Speed Management and Speed Limits

Speed management (including appropriate speed limits) is also considered a Safe System treatment when the required level of speed compliance is achieved. Research into the relationship between speed, crash types and outcomes provides asset managers with some guidance on Safe System speed management. Speeds of around 30 km/h or less are required to minimise deaths and serious injuries to vulnerable or unprotected road user, including pedestrians. These speeds are common on many local roads in Europe, but less so in Australia and New Zealand. Speeds at this level would also be required at key points where vulnerable road users are present on arterial roads. Where speeds higher than these are desired, appropriate infrastructure is required to ensure death and serious injury outcomes are avoided, for instance, the use of adequate separation.

Speeds of around 50 km/h are appropriate at intersections, as this is the speed above which the chance of death and serious injury rapidly increases in the event of a crash involving vehicles. Speed can be managed at intersections through good design. For example, roundabouts provide geometric constraints that act to manage speeds. Lower speed limits have been trialled at intersections, but as yet there is limited evidence to show that speed limits used alone at intersections have a benefit in terms of speed reduction or safety improvements, i.e. they must be used in conjunction with engineering measures (Austroads 2010a). Variable speed limits, and vehicle activated speed limits at intersections, may be of benefit and trials of these treatments are currently being undertaken.

Speeds of 70 km/h or less are considered appropriate, given current vehicle designs, to minimise death and serious injury from head-on crashes. Rural speed limits of 70 and 80 km/h on typical minimal standard undivided roads are being investigated in various countries around the world. Where higher speeds are required, roads need to be divided to prevent death and serious injury from head-on crashes. Lower speed limits in the vicinity of rail crossings are also being trialled in Western Australia, with speed zoning of 80 km/h applied in a number of 110 km/h zones. Significant reductions in speed have been observed (MRWA 2012).

It is clear from this that there is a strong interplay between speed and infrastructure provision. In order to move towards Safe System outcomes, speeds will need to be below the critical levels identified above, or if higher speeds are required, infrastructure must be provided to protect road users in the event of driver error.

2.2.3 Intelligent Transport Systems (ITS)

ITS is being used for improving road safety in many ways. Some examples are the Advanced Traveller Information Systems (ATIS) on Variable Message Signs (VMS), Variable Speed Limit Signs (VSLS) for regulating road speed, Queue Detection Systems, Over Height and Over Length and Over Weight Detection Systems. When integrated with road design, these ITS systems provide a safer environment for road users and maintenance service providers.

Responses to Safe System through changes in road design, construction and maintenance cannot be implemented in isolation. Network operations and asset management optimisation strategies should be integrated with Safe System philosophies and set the direction for implementing safe system initiatives through these activities, integrating these safe system initiatives with ITS strategy for road corridors and the road network in general.

Cooperative Intelligent Transport Systems (CITS) is the expansion of traditional ITS to include vehicles, where the vehicles communicate with each other and/or with the infrastructure. Various CITS solutions are available to support Safe System outcomes and are anticipated to address key crash types through various means. For example, it is expected that lane departure systems will assist in preventing (and possibly eliminating) run-off-road crashes and vehicle-to-vehicle systems will help prevent intersection crashes. Other technologies may act to prevent head-on and intersection crashes. Intelligent Speed Assist, a technology that either alerts motorists if they are speeding, or actually controls vehicle speeds, has been successfully trialled in Australia and elsewhere.

It is important to note that it will be several years before such systems are standard on new vehicles, and then at least a decade before these new technologies filter throughout the vehicle fleet. However, once in common usage, these systems will have significant impacts on the provision of infrastructure, and may reduce the need for at least some Safe System infrastructure solutions, e.g. wide clear zones.

2.3 What is Different about the Safe System Approach?

The traditional approach to road safety underpins industry progress toward the Safe System approach, recognising the contributions of road users, vehicles, infrastructure and the operating environment to all crashes. Road safety research in these fields has provided the platform from which Safe System philosophy and interventions have evolved.

A move to a Safe System is not a move away from road safety approaches and practices, but rather continuous improvement for better safety outcomes where there is less likelihood that human error results in a FSI outcome.

Historically road safety was targeted to address the worst crash sites first. Budgets were typically project specific and reactive, based on past crash history. Upon addressing the worst black spot sites, road safety practitioners began to consider proactive program related treatments based upon potential risk, e.g. traffic and infrastructure characteristics. This shift is consistent with Safe System thinking.

A challenge under a Safe System approach is to ensure greater usage of treatments that will provide Safe System outcomes, as identified in Section 2.2.1, and that implementation approaches continue to evolve in an integrated, multi-disciplinary, systematic and data-led manner. However, whilst Safe System has evolved from road safety, it does require road agencies to think and respond differently to road safety issues.

There are some distinct differences between the old road safety paradigm and the new Safe System approach that will require road managers to raise the bar and respond differently to address risks of network configuration and condition. Some examples of this paradigm shift are listed in Table 2.2.

Table 2.2: Comparison between 'old' road safety paradigm and Safe System approach

Issue	Old road safety paradigm	Safe System approach
Understanding of biomechanical tolerances (i.e. critical speeds at which death and injury occur for different crash types)	Information on biomechanical tolerances available, but not core to understanding of how to address risk.	Biomechanical tolerances are core to vision of eliminating deaths and serious injuries. Understanding of these tolerances changes the approach in terms of the treatments used, and also brings appropriate speed management, and speed mitigation responses, more to the fore.
Road user error	It has been known for some time that road users will make mistakes (e.g. 90% of crashes caused by road user error) and also that infrastructure improvements are an easier way to improve safety (even for crashes caused by human error). However, this human error has often been used as an excuse for inaction, or used to direct focus towards improving driver behaviour rather than infrastructure improvement.	Fundamental to the Safe System approach is that road users will make errors, and that a system-wide response is required to address this. Therefore, it is unacceptable that because crashes were caused by human error, there is little or nothing that road managers can do to address this. Almost all crash types, including those resulting from human error can be reduced through vehicle and infrastructure improvements, and the severity dramatically reduced.
Shared responsibility	Focus on driver education and training to address road user error. Therefore, less responsibility for road managers to address crashes caused by this error.	Road managers and road designers who are acting on their behalf need to share responsibility for improving road safety, even when crashes are caused by road user error. This implies the need for providing and maintaining a more forgiving road and roadside environment.
Design requirements	A reasonable understanding of the effectiveness of different treatment types, but often a focus on treatments that are of low cost/high BCR that reduce crashes, but that may not act to eliminate death and serious injury.	There is a need to provide infrastructure that will assist in eliminating death and serious injury. A more forgiving road (including roadside) environment is required. This can be through speed management (in line with knowledge about biomechanical tolerances) and with use of appropriate infrastructure (e.g. separation of road users travelling in different directions, separation of vehicles of different mass, or roadside protection).
Crash severities addressed	Fatal crashes seen as the most important, followed by serious injury and then minor injury. However, total crashes (i.e. of all severities) often used to identify problem sites and as the basis of research.	Starting point should be the aim to eliminate death and serious injury. Identification of risk should have a focus on these crash types. Information on minor injury crashes may be useful in providing information on crash locations and causation (and hence potential for future fatal and serious injury), but are not the core focus.

2.4 Relation to Road Asset Maintenance Practices

For many years road maintenance practices have also had a safety focus, with this reinforced in recent years through clarification of the need for road agencies to act consistently and reasonably in managing and maintaining the safety of the network. In some jurisdictions this has led to legislated requirements for formal road management plans which contain specific routine maintenance standards for reasons of safety and to support traffic use. These routine maintenance standards relate to the management and/or repair of 'hazards'. Consequently, response times and inspection frequencies are set according to an assessment of risk, taking into account factors such as road classification, road type and the volume and type of traffic. Where a particular level of defectiveness is not defined as a hazard, investigatory criteria are set and responses are considered within the scope of routine and periodic maintenance programs[3]. Both considerations are also consistent with a Safe System.

Asset maintenance can also extend to more substantial works where incremental improvements are made to the existing road network (so called 'Brownfield' sites) to enhance its traffic and safety performance. These issues are discussed in Section 3.4.3, and offer significant opportunities for asset managers to contribute to a safer road system.

Finally, outcome based KPIs, e.g. number of fatalities, have also been used to guide road safety and asset management programs and continue to be used and evolve for use under a Safe System. This requires additional KPIs to be specified, e.g. the number of lives saved, and considered in the planning and reporting processes, this being consistent with national and state and territory targets.

[3] For further elaboration of routine maintenance standards, and periodic maintenance interventions see Commentary D (Service Levels and Intervention Levels) and Commentary F (Managing Risks) of the Austroads *Guide to Asset Management*, Part 1, AGAM01-09 (Austroads 2009).

3 CONVERGENCE OF ASSET MANAGEMENT AND SAFE SYSTEM

3.1 Aims of Asset Management

There is considerable community investment in Australian and New Zealand roads and related assets which must be maintained, improved and expanded in order to continue to provide effective access to road users and meet community requirements. Road agencies expend large amounts of community funds on managing road networks and good governance requires that these funds must be effectively targeted.

Asset management is the discipline used to support and guide road managers to ensure funding is targeted towards the best use of limited resources to deliver the maximum community benefit. Road asset management is defined in the *Guide to Asset Management* (GAM) (Austroads 2009) as follows:

> Road asset management is a comprehensive and structured approach to the long-term provision and maintenance of physical road infrastructure using sound engineering, economic, business and environmental principles to facilitate the effective delivery of community benefits.

The Austroads Assets Strategy defines the key objective of asset management as the minimisation of whole-of-life-cycle costs of road assets, whilst aiming to meet the needs and expectation of the community and other stakeholders who use or benefit from the asset, and to fulfil government objectives in terms of safety, environment and equity of access.

3.2 Similarities and the Basis for Convergence

Road asset management is based on meeting customer and service requirements and requires decisions to be made to maintain existing assets and road access, or replace or significantly enhance the existing assets or provide an alternative service, e.g. replacing a ferry or barge service with a bridge asset.

Safe System is about ensuring the existing or new/enhanced infrastructure associated with road access provided by agencies is forgiving of driver error. A quandary therefore arises from budget and funding considerations about what is the minimum level of infrastructure required to practically maximise safety outcomes.

Asset management systems and processes provide a means to demonstrate ‘reasonableness’, which is a term used by the legal system to determine adequate or minimum infrastructure requirements. Asset managers have always worked with budget limitations and used prioritisation and optimisation procedures to allocate funds in a reasonable manner. Safety managers work with the same limitations but often focus on capital improvements targeting one outcome area: safety.

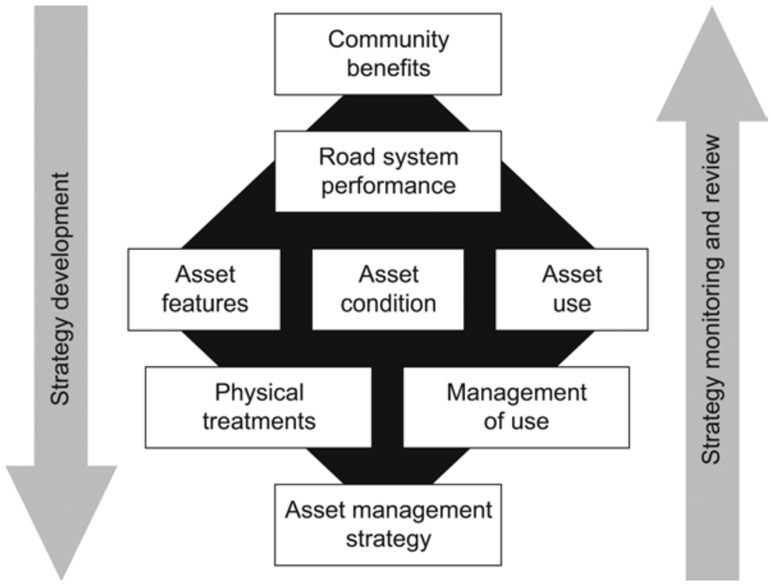
Safe System concepts are described by Wegman and Aarts (2006) and clearly align with accepted asset management practices. They include a classification of the road network in accordance with its functionality and assigned levels of service (LOS), which in turn contribute to the homogeneity and predictability of the driving experience.

Best practice asset management is a continuous improvement process; the Safe System provides the vision for iterative continuous road network safety improvements.

The Safe System is also a means to better improve road safety outcomes in a systematic manner through asset management driven data systems in addition to traditional crash data systems.

Road safety, the Safe System and asset management are all risk management approaches that weigh risk likelihood and consequences when determining treatments and management options. However, what risks are considered and how those risks are prioritised and processed varies between the disciplines.

The separate elements of road asset management are illustrated in Figure 3.1 and provide a basis to integrate asset management and the Safe System approach.



Source: Austroads (2009).

Figure 3.1: Elements of asset management for road networks

Like asset management, a Safe System is a systematic and network level approach, and therefore fits with a strategic based approach.

From an asset management perspective a Safe System is not about denying asset preservation benefits or elevating road safety benefits over and at the expense of other community benefits, but rather striving to achieve the maximum of all benefits in a balanced manner within a system that means people should not have to die or be severely injured because of a mistake. The challenge is in understanding how to define, apply and realise Safe System outcomes in a way that appropriately balances their value with and against other community requirements or benefits.

The science of road safety and the Safe System approach provides an established and extensive body of knowledge to help define community inputs to the asset management planning process (e.g. biomechanical tolerances). This knowledge can lead to establishing new criteria for consideration when undertaking a gap analysis, selecting treatments and optimising or prioritising the work program. It fits with the common need to prioritise and optimise under budget constraint, and in the context of a Safe System it requires consideration of the following:

- Harm minimisation strategies, comprising treatments and associated infrastructure characteristics, which are consistent with the objectives of a Safe System (near zero deaths and serious injuries), particularly through the use of primary treatments.
- Harm reduction strategies, which reduce deaths and serious injuries, but not necessarily to Safe System levels. Such approaches typically make use of supporting treatments.

In a Safe System context the need is to strive for the elimination in FSI. In this context a suitable optimisation objective would be to **maximise the reduction in FSI within fiscal constraints**. Reporting on FSI reductions resulting from the application of different strategies, to the extent possible, including an appropriate mix of physical and road use management measures, provides a basis for comparing the efficiency of different strategies and setting reasonable targets.

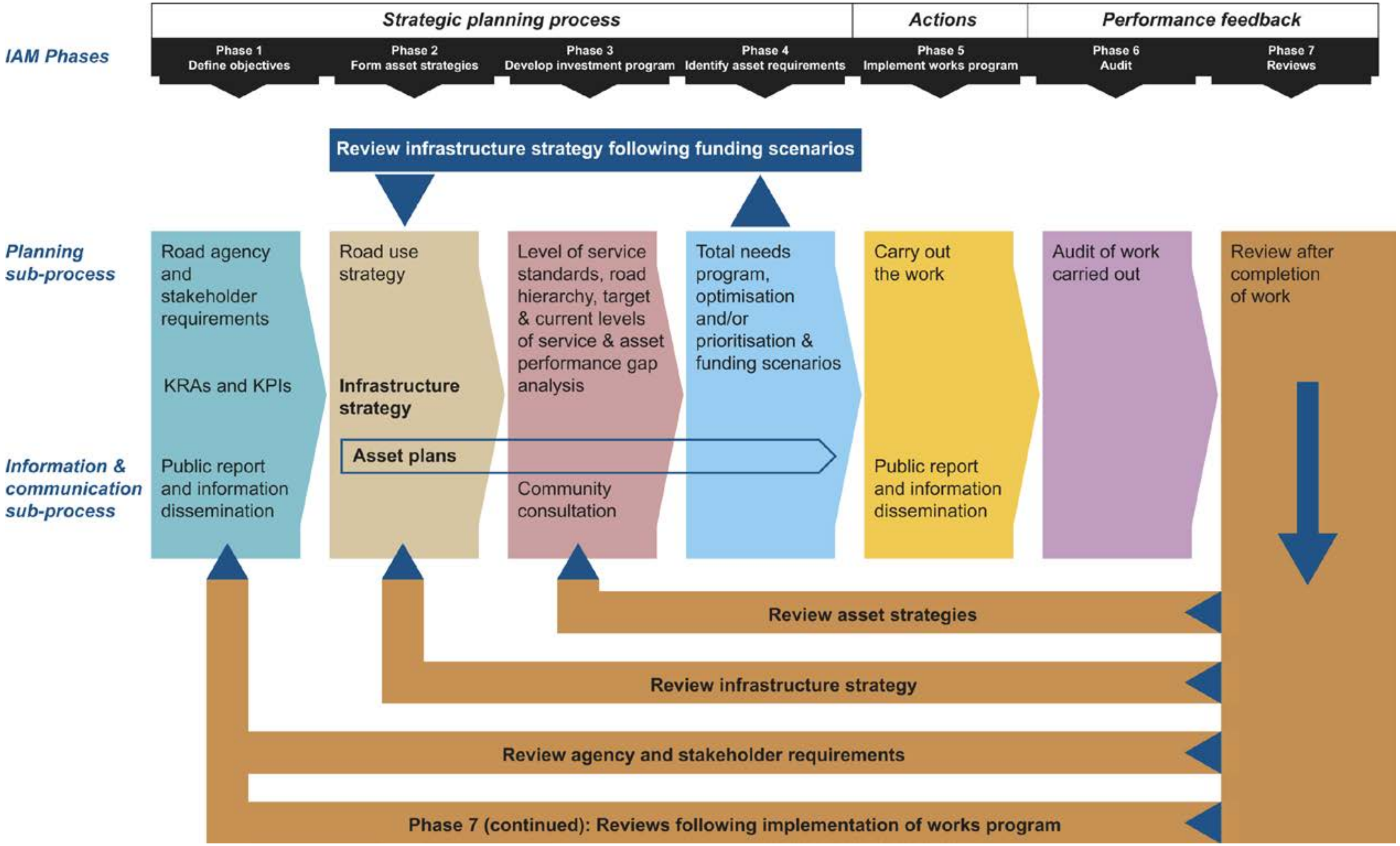
The significant community drivers for safer roads combined with an established scientific basis may conflict with other community requirements, making the job of balancing Safe System outcomes (no FSI) with other community requirements (e.g. access) challenging.

3.3 An Asset Management Framework for a Safe System

Asset management is a well-defined and established discipline with tools, processes, methods and science used to define, apply and realise community benefits. This provides objective data and information into the decision-making process to enable better decisions, and achieve policy objectives. These tools and processes can similarly be applied to achieve Safe System policy outcomes.

An overview of the asset management process is presented in Figure 3.2. This framework was reviewed and found to provide a suitable, integrated platform from which asset managers can implement the Safe System. It is anticipated appropriate Safe System inputs, decision criteria and outputs can be developed.

Asset managers also need to make decisions in the knowledge of road use management (RUM) strategies and, where they are not responsible for network operations, provide feedback to the road use managers, i.e. those responsible for network operations, in order to ensure the optimal use of assets.



Source: Austroads (2009).

Figure 3.2: An overview of the asset management process

The IAM framework has been adapted by many road agencies as part of their business process, and has common elements with a number of similar frameworks. It provides the foundation for the Austroads Guide to Asset Management, which requires asset managers to ensure that:

- assets are managed to conditions which are appropriate for intended use
- the immediate and long-term budget requirements, together with the consequences of budget variations, are explicit
- risks associated with asset use are managed, recognising the duty of care owed to the public, with emphasis given to safety and minimising environmental impacts.

Specific adaptations of the IAM framework by road agencies elaborate the processes in greater detail and also assign specific responsibilities and accountabilities between organisations and amongst organisational units.

New criteria will be required to guide asset managers in responding within the Safe System context. How these new criteria will be defined is fundamentally different to previous asset management approaches, i.e. they will need to include consideration of human biometric tolerances and the operational environment of the road and roadside. However, significant input to their definition is already provided by current road safety science. These criteria require infrastructure characteristics and the management regime to be assessed considering Safe System principles and human tolerance, and provide a basis for working towards the achievement of Safe System outcomes.

3.4 Opportunities for Integration

3.4.1 Overview

The Austroads *Guide to Asset Management* provides exceptional detail and guidance to practitioners on good practice asset management. It is not the purpose of this report to reiterate that guidance, however, highlighting some key points demonstrates how existing asset management practice and processes can support the integrated implementation of the Safe System approach.

Road agencies should decide in conjunction with customers and stakeholders the requirements of the road network and, in turn, define appropriate customer levels of service that will provide for those requirements. They should convert the customer levels of service into technical levels of service that drive priorities for infrastructure improvement and the routine and periodic maintenance and renewal works, and associated minor improvement works implemented over the entire network. Whilst the community may aspire to have a perfectly safe system, the immediate goal is to make improvements to the safety of the current system.

Furthermore, the response by asset managers should consider how they can impact on the majority of the network they maintain (while capital improvement projects occupy the remainder) in terms of achieving Safe System outcomes[4].

[4] However, the distinction between maintenance and traditional capital-funded infrastructure improvement projects is becoming increasingly blurred, particularly as safety-focused improvement projects are applied to the network. These are targeting deficiencies in the network from a safety viewpoint, and examples shown later suggest they are addressing a significantly higher proportion of the network than typical capital renewal projects. They also have the potential to augment asset maintenance (and preservation) programs if they are well planned and coordinated.

The key requirements to achieve this first involve:

- Setting objectives, based on a defined policy, and associated responsibilities.
  - — This is the first phase of the Austroads asset management process Figure 3.2.
- Defining strategies including a network vision, with a defined hierarchy comprising the role and function of parts of the network and target levels of service, and evidence based guidelines to aid in the selection of solutions, including a mix of road use management and infrastructure responses.
  - — Phases 2 to 4 of the Austroads asset management process are integrated and iterative phases to confirm the funding aligns with an achievable strategy Figure 3.2.

As an evidence driven discipline asset management should pursue best value for money decision making through prioritised and programmed investment. Value for money can be defined as delivering the most value to customers for the least long term cost, and can be achieved through the use of:

- Defined technical levels of service

  This requires road agencies to consider how assets will reduce the likelihood and/or severity of crashes. These need to be achievable in the targeted timeframe and sustainable. The importance of assets such as signs, lines, barriers etc. need to be taken into account, and standardisation of approach in setting risk level and the contribution sought from each element of infrastructure is needed.
- Intervention triggers

  When setting safety intervention triggers (service levels at which maintenance or renewal works are initiated) the following factors need to be determined:
  - — What circumstances create a safety risk and how great is that risk?
  - — How great must the safety risk become before a response is triggered?
  - — What should the response be at different levels of risk?
- Monitoring condition and performance

  Monitoring is needed to identify the need for safety related maintenance, based on when the safety intervention triggers are reached, and renewal works and the effectiveness and efficiency of those works.
- Benefits of treatments

  Evidence reported to date has generally demonstrated the benefits of installing new safety features where there were none before, and extensive research-based information exists. Evaluation of alternatives should always be considered, and the social costs determined based on adoption of the willingness-to-pay approach. There is, however, less evidence relating the safety benefits to be gained by restoring the quality of elements from various states of deterioration than exists for road surfaces and pavements. Further work is needed in this area to fully understand the benefits to be achieved.
- Prioritisation and programming of maintenance and renewal strategies

  The adoption of safety levels of service targets in response to the Safe System approach requires the extension of the existing approach to prioritise and program maintenance and renewal to encompass safety outcomes as well as the more traditional service targets.

When adopting a road safety level of service, in order to address the full scope of the crash risk, road and roadside elements should be considered that:

- reduce the likelihood of crashes
- reduce the consequences of crashes.

Agencies should also ensure that the adopted levels of service are achievable in the targeted timeframe and sustainable. Should the desired levels of service not be achievable it may be appropriate to modify speeds. Adopting a speed management policy should be an element of an asset manager's intervention strategy, particularly in a constrained funding environment which is a fact of life for most road agencies, at national, state, territory and local government level.

In summary, there is strong evidence that current asset management processes can be extended to cover those required in a Safe System approach. However, there is a clear need to identify the linkages between a range of asset conditions and crash outcomes to allow evidence based prioritised investment in the delivery of optimal maintenance practices within the Safe System.

3.4.2 Specific Drivers

National, state and road agency strategies meet requirements to varying degrees and provide a basis for action and monitoring trends. For example, the Australian *National Road Safety Strategy* (NRSS) (Australian Transport Council 2011) (and those of most states and territories) aims for a 30% reduction in FSI by 2020 and for 'Safer roads' emphasises:

- improved standards for design, construction and operation
- focus on new roads and upgrades
- increased spending on safety focused road works
- risks assessed and investment refocused
- run-off-road, head-on and key intersections
- adoption of a willingness-to-pay basis for social costs
- whole-of-life-cycle-costs and benefits
- accountability of road agencies accepted.

In addition, a number of road agencies have established accountability frameworks for internal use, and have published strategies and associated action plans, which:

- describe the areas of focus, associated objectives, and policies
- identify initiatives and actions
- assign specific tasks to lead directorates and timeframes.

3.4.3 Developments in Current Practice and Distinguishing between Brownfield and Greenfield Sites

A number of road agencies possess asset maintenance (and management) policies and guidelines which already embrace safety to a significant degree as part of the suite of objectives they support and address the management of the existing network in an integrated and overt manner. For example, in NSW the RMS *Brownfields Road Design Guidelines* (BRDG) (RTA 2007) have been created and applied for a number of years to address the multiple objectives on the network. They distinguish between:

- **Brownfield sites**, being locations on existing roads where work proposals are based on retaining the existing formation to the greatest extent feasible, and improving the safety performance within the practical limits of the candidate sites and funding. This means that existing community resources are recycled, existing road corridors are largely kept and any cost savings are used to obtain a pavement service life that is close to the original design intention across the whole of the arterial road network.
- **Greenfield sites**, being locations where the existing land zoning is changed to allow a road to be built. Such a change may have been made many years earlier when a road corridor was set aside. Accordingly, the road alignment is relatively unrestricted in terms of the geometry that can be used. These sites are generally away from existing roads and do not need daily traffic control. At such sites all the associated road infrastructure must be provided and, whilst often involves quite major work, the Safe System philosophy is an integral part of the design and construction of the project.

The distinction recognises that road asset maintenance funding aims to deliver the corporate outcomes of road safety, route reliability and retained value, all within a constrained funding environment, with the following emphasis:

- The BRDG have been prepared to provide designers, design staff and others with a process and methodology for developing the **designs for asset projects**. They provide designers the ability to determine the appropriate geometric criteria to be used on a route or project, recognising that, due to limitations of funding, fundamental geometric standards may not be possible at some ‘brownfield’ sites on the existing road network.
- From a **safety** perspective, the priority is to reduce the number of fatalities and casualty crashes that occur on roads.
- From the perspectives of **asset management**, **reliability**, **maintenance** and **retained value**, this would include activities such as carrying out routine maintenance, re-sealing and waterproofing the road surface, and reducing pavement roughness. Rehabilitating poor or degraded pavement sections will allow the asset to achieve its full design life, while rebuilding of the road pavement will renew the asset life cycle.

Such statements clearly confirm that integration is not new, but in practice may be achieved to varying degrees. However, it is vital in order to achieve objectives and minimise costs.

More specific guidelines have also emerged in recent years which specifically target safety from an asset management perspective and embody a Safe System philosophy; see for example the New Zealand *High Risk Rural Roads Guide* (NZTA 2011). In a further example, VicRoads *Safer Roads Infrastructure Program* (SRIP) (VicRoads 2012) and its accompanying guidelines illustrate how road agencies are responding in aiming to maximise Safe System outcomes within the constraints of an existing network. Others have attempted to define the attributes of a Safe System as it may relate to road hierarchy, this being very important in assessing whether an infrastructure gap exists (MRWA 2011a).

3.4.4 Development of the Australian National Risk Assessment Model and Associated Best Practice

The Australian National Risk Assessment Model (ANRAM)[5] is currently nearing completion (at the time of writing this report), which is also paralleling developments in New Zealand and will utilise the iRap/AusRAP rating system.

In Australia, ANRAM has developed in response to directions set in 2008 by the Australian Transport Council (now known as the Standing Council on Transport and Infrastructure) (Australian Transport Council 2008):

- Establishing better linkages between road construction and safety outcomes through adopting risk-based approaches to the road network and developing targeted safety upgrade works for high-risk black spots.
- Development of programs and treatments to address single-vehicle run-off-road crashes and other rural crash problems.

The Australian *National Road Safety Strategy 2011–20* (Australian Transport Council 2011) supports the above points, in stating that all levels of government are to:

> …have assessed risk on their road network and re-focused road investment programs to treat higher-risk sections of the road network (road segments, traffic routes and defined areas) in addition to more targeted black spot programs. (Australian Transport Council 2011, p. 54)

Further, the Strategy also includes the following objective:

> Complete Austroads risk-based assessment model; and then systematically assess risk levels for highest volume roads and prioritise road sections for safety improvement. (Australian Transport Council 2011, p. 55)

The ANRAM will provide a means of reporting the performance or assessment of high-risk roads in a consistent manner across Australia. In a similar way to New Zealand, where daily road fatality briefing reports include the road star rating[6], briefing reports for Australian Transport Ministers could include the ANRAM generated risk rating for the roads on which the fatalities occurred. This simple approach helps to build consciousness of the role road infrastructure safety plays in achieving the Safe System objectives.

ANRAM, which is now in its final stages of development, will provide a system that:

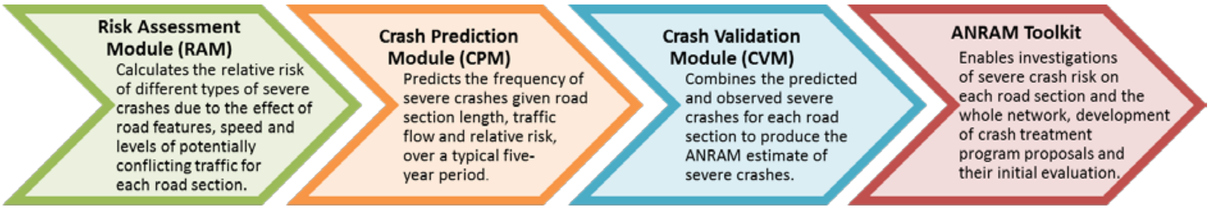
- determines collective fatal and serious injury risk at a network level, reported for individual road sections (recommended 3 km). The ANRAM estimate of severe crashes is based on road stereotype, engineering features, speed, potentially conflicting traffic and severe crash history.
- will be useful in monitoring changes in collective risk across the road network over time, prioritising high risk sections, development of mass treatment programs and measuring progress towards the Safe System
- accounts for individual road user risk through use of the ANRAM Star Rating Score (SRS) – this is a measure of the inherent risk to safety of the road features

[5] The ANRAM system is undergoing finalisation through Austroads project no. ST1571. Trials have taken place in Australian states, including South Australia as described by Bekavac et al (2012).

[6] Such scores are applied by iRAP (iRAP 2012), and the related AusRAP (2012) and KiwiRAP (2012), tools, and are used by ANRAM.

- is comparable with observed crash history, and could be used to seek out routes where road user safety issues dominate and which could be pursued through infrastructure modifications or enforcement and education strategies
- provides basic analytical and decision support features enabling users to carry out investigations of severe crash risk on the road network and analysis of potential treatment programs, including basic economic evaluation.

Figure 3.3 illustrates the structure of the ANRAM system. It is important to note that these modules will rely on the supply of appropriate data inputs by road agencies (Appendix A). This will require an extension of current data collection systems. However, because the ANRAM and similar asset management tools are fundamentally data driven and are focused on assessing the existing network, they provide an opportunity for encouraging common data collection and providing an input to the formulation of more integrated investment and maintenance programs.



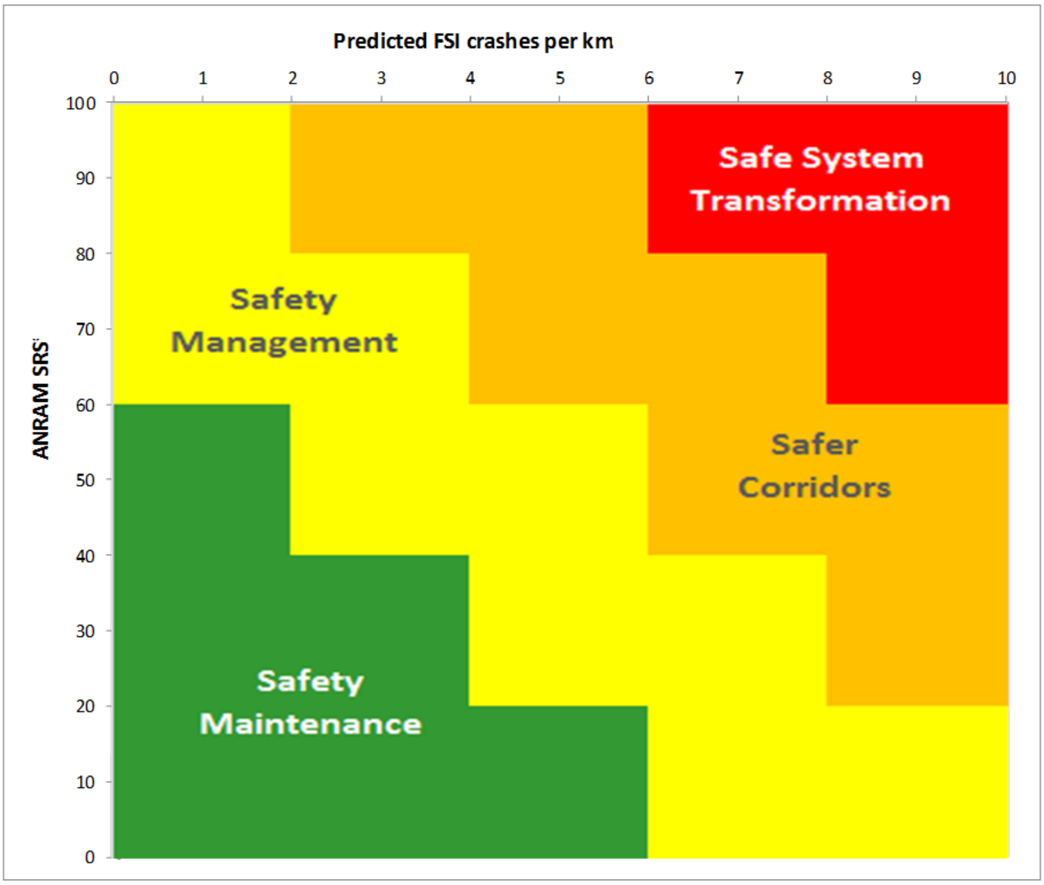
Source: Personal communication ST1571 project team.

Figure 3.3: ANRAM overview

One proposed approach in applying ANRAM in a Safe System context draws on concepts presented in New Zealand Transport Agency's *High-risk rural roads guide* (2011). The proposed approach provides a useful classification which embodies the Safe System philosophy and intended outcomes, by taking a strategic view of how the collective and individual risks[7] prevalent on different parts of the network could be used to influence the approach to road maintenance and safety investment. Figure 3.4 presents an example of this approach in the form of a risk matrix. The collective risk of severe crashes is presented on the horizontal axis (Predicted FSI per km[8]). The individual risk is presented on the vertical axis (the section-averaged total ANRAM SRS).

[7] **Collective risk**, or crash density, is defined as the average annual number of high-severity crashes per kilometre. This data is relatively easy to collect and is available from crash statistics from road or transport agency records. **Personal** (or individual) **crash risk** (or crash rate) is a measure of the likelihood of an individual road user being involved in a crash as they travel the road in question, and is usually reported per 100 million vehicle kilometres travelled (VKT). Calculating the personal crash risk is more complicated because of the need to establish the volume of traffic on the section under consideration (annual average daily traffic – AADT). Alternatively, typical crash rates may be estimated based on design elements for a section of road. These estimates are based on relationships between these design elements and crash outcomes, and are particularly relevant in rural areas where crashes are widely dispersed and no crash history exists.

[8] Predicted FSI indicates the collective severe crash risk due to engineering features, speed, traffic flow and potential vehicle conflicts.



Source: Risk matrix based on Durden and Jansson (2012).

Figure 3.4: Example of a risk-based approach to identifying and prioritising road safety actions

Examples of the application of the framework include:

- **Safety Maintenance** is appropriate where personal crash risk and crash density is low, and there is little evidence of a serious safety problem. However, there may be scope for treating crash clusters or shorter sections of the route for which crash data or other tools such as KiwiRAP and ANRAM predict higher levels of risk.
- **Safety Management** responses would be well suited to a common scenario on road sections found in a rural or local government setting, where low traffic volumes and legacy road design contribute to unsafe travel for relatively few road users of that section (high individual risk). The result of low traffic volumes is the low collective risk and possibly no crash history. Recognising the low economic return on investment into Safe System transformation works for such road sections (e.g. road duplication, freeway-style interchanges), the framework proposes a low cost approach to treatment selection, preferably extending across the entire network of similar roads.
- **Safer Corridors** is likely to be effective in circumstances such as an inner-metropolitan arterial, where much of the viable road safety investment has occurred already, and the high collective risk is often driven by high traffic volumes and mixed road use (e.g. pedestrians, public transport, and cyclists). In such a context, a targeted black spot approach and other forms of road safety intervention such as route safety reviews and strategic reassessment of route function may also be highly effective (e.g. rerouting through traffic to safer routes, and/or pedestrianisation).

- **Safe System Transformation Works** e.g. a major upgrade or provision of an alternative, safer standard route, should be considered on road sections with higher volumes and constrained design or poor alignment. These typically include rural/outer-metropolitan highways which are likely to score relatively highly in both collective and individual risk areas.

Whilst asset managers have greater direct influence on Safety Management and Safety Maintenance, they should be involved in decisions related to Safe System Transformation Works and Safer Corridors because these circumstances will provide opportunities to optimise treatments which address multiple objectives and to ensure sufficient account is taken of future maintenance and renewal needs.

Building on outputs provided by ANRAM, this latter approach could conceivably be better addressed by facilitating greater integration at the planning level and the application of a common suite of tools to optimise safety, asset preservation and road use outcomes.

4 ACHIEVING INTEGRATION

4.1 General Requirements

The following emphasis is proposed to achieve the goal of integrating asset management and the Safe System philosophy:

1. A balance must be struck in order to contribute to the multiple objectives sought, with a Safe System being one of a number of competing community needs to be delivered within fiscal constraints by harnessing cross-disciplinary resources and delivering appropriate solutions. Community needs are articulated in national, state and territory road safety strategies, and hence must be accounted for in plan development and implementation.
2. Specific approaches and actions asset managers can implement which are clearly within their control and/or influence need to be identified, starting from strategy development, tactical plan development, through project planning, implementation, and audit and review. These actions should be agreed with and complement those by others within each organisation, and other road and transport related organisations.
3. Priorities need to be set, but as noted in (1) above these should aim to strike an appropriate balance across different objectives such as safer roads, reliable access, efficient travel, preserving assets, and contribute to greater social cohesion, and sustaining and improving the environment and heritage value. This will require positive steps to address the needs of rural, urban and remote communities, recognising that the solutions need to be tailored to the factors which affect the performance of different parts of the network. Managers should also not need to be in a position of constantly seeking advice on what objectives to prioritise, once policy direction and funding are provided.
4. Where new or alternative infrastructure solutions are introduced more widely, the costs of their initial provision and, in particular, their upkeep and maintenance must be addressed to ensure benefits are realised.
5. Safe System Practitioners should use and adapt existing asset management procedures and processes to implement Safe System and embed Safe System philosophies into the daily decision-making processes of road agencies.

4.2 Specific Process Requirements

To help achieve such goals it is useful to define an overall framework comprising specific processes, output requirements, information and knowledge, necessary systems, tools and skills.

In formulating and applying such a framework, the following questions need to be answered:

- What should the framework contain, and where should we currently be? For this there is a need to define and/or adopt contemporary best practice.
- Where are we now, and what do we have? This can be approached from an industry-wide, organisational, division or a team view, and assessed against contemporary best practice.
- How do we close the gap identified above (and who and how)? Assessing and learning from what others have done is a good start.

Based upon practitioner feedback during this project a preliminary table of key process requirements has been developed. Table 4.1 presents the proposed key process requirements for agencies wishing to implement Safe System through asset management. Agencies can use this table as a self-assessment tool to determine their capacity to adapt and use current asset management practices based on their existing application of the Austroads asset management framework (Figure 3.2).

The requirements focus on the asset management phases (1 to 4) as a strategic view provides greater opportunity for integrated solutions, and seeks interaction during the formulation of policies, strategies and plans. Once plans, and projects, have been developed there is less opportunity to maximise beneficial outcomes.

Table 4.1 also describes the purpose or need for the specific requirement. Examples are described in the following section where a summary of knowledge, practice and case studies are presented which aligns with the framework. The examples relate to different applications contexts, e.g. maintenance, operations, brownfields or greenfields.

Table 4.1: Proposed key process requirements for achieving a Safe System within an AM framework

Requirement	Purpose
Phase 1 – Objectives	
1.1 Safe System policy exists with clear priority actions/strategies and quantitative, time-bound targets (reduction in FSI with realistic interim 3–5 year targets) and associated resources which provide a basis for AM leverage/influence.	Existence of a balanced and resourced Safe System policy is fundamental to addressing agency objectives, whilst also fulfilling other commitments to access, network efficiency, etc.
1.2 The policy (or strategy) accounts for contributions by different stakeholders/players, and commitments to its success are widely publicised, and specific responsibilities are documented in a corporate asset management/Safe System accountability framework.	Clear assignment of responsibilities, and other roles/ interests to manage delivery of objectives and allow asset managers and road safety managers and other key corporate stakeholders to engage and understand their roles/accountabilities in any key initiatives/strategies to which the road agency contributes.
Phase 2 – Asset strategies	
2.1 A network vision exists which articulates how the network will be managed and developed to meet Safe System needs, and is consistent with the stated Safe System policy and other corporate objectives.	Provides input to strategy development, including component parts, responding to community and industry needs, and the network is operated and developed to achieve stated Safe System policy.
2.2 A clearly defined hierarchy, covering role and function, and the level of service (LOS) of different parts of the network exists to support the vision.	Supports network vision and provides a focus for mitigation strategies and improvement actions, and the analysis of factors affecting the safety performance of individual parts of the network.
2.3 A balanced strategy has been developed and adopted by stakeholders which supports the policy and network vision, including other targets such as route security, and the overall targets (in Phase 1) have been disaggregated considering risk and equity.	To optimise contributions from all stakeholders, through safer infrastructure (both maintenance and improvement or provision), speed management, vehicle technology and road use, and therefore maximise the reduction in FSI, whilst recognising the need to allow a trade-off between safety and other asset management targets (providing a defence against civil action).
2.4 Evidence-based guidelines (for both brownfield and greenfield sites) exist to inform data collection, risk assessment, treatment selection and prioritisation, and are applied to ensure a balance between the use of primary and supporting Safe System treatments and alternative build or non-build solutions.	To inform the development of road use and infrastructure (management and investment) strategies and associated funding needs, and program and project development.
2.5 The proposed suite of solutions have been communicated to and accepted as being workable by all stakeholders and contributors and benefits are well understood.	Offers opportunities to optimise spending and maximise FSI reduction with the support of stakeholders.
Phase 3 and 4 – Investment program and Identify asset requirements (also known as tactical planning and programming, and project development)	
3.1 The required time-series data exists at a sub-network, route and link level, and is regularly applied to: ▪ assess asset related risks ▪ quantify the occurrence and density of crashes, and crash types ▪ assess crash trends (all, and FSI), and any associations with road use.	Allows performance/risk to be better understood and possible mitigation and improvements to be well targeted.
3.2 Crash performance of different (primary and supporting) treatments is known.	Essential input to treatment selection, prioritisation and optimisation.

Requirement	Purpose
3.3 Comprehensive cost data exists.	Allows better estimation of the provision and maintenance of all assets, and asset lives.
3.4 Appropriate processes, systems and tools are in place to utilise the data and models to inform the preparation of prioritised and optimised treatment programs, and allows trade-offs to be assessed between relative gains in reduced FSI and route security, etc.	To inform the preparation of programs which maximise the reduction in treatment strategies in reducing FSI within budget constraints.
3.5 Feedback loop.	Provide the opportunity to review and revise overall targets in light of budget availability and assessed network conditions.
3.6 Communications.	Informs stakeholders and the community of proposed actions and associated impacts and benefits.
Phase 5 – Implementation	
5.1 Manage risks to road users and the liability of road agencies, and make the maximum impact for the funds available to progressively reduce FSI as well as achieve other asset management targets.	Minimise risks to road users and liability of road agencies within existing policies/frameworks having prioritised and utilised all funds available as effectively and efficiently as possible.
5.2 Implementation of management controls.	Ensure that delivery, comprising physical projects, network operation and maintenance, take place as intended and changes in scope and cost variations are minimised.
5.3 Sufficient flexibility exists to allow refinement at a site or road link level.	Provides opportunity for justifiable changes based on site details and operational conditions.
Phase 6 – Audit	
6.1 Project and program audits.	Ensure actions are delivered broadly in line with original scope and budget, and reasons for non-performance (both cost and benefit related) are understood.
6.2 Asset value.	Ensure impacts on asset value are accounted for against program spend.
Phase 7 – Reviews	
7.1 Comprehensive periodic reviews of all components of the framework.	Allows achievement of network performance indicators to be monitored against inputs.
7.2 Incorporate learning from annual and periodic reviews into the development and modification of the overall process and requirements.	Ensure continuous improvement.

5 SAFE SYSTEM AND ASSET MANAGEMENT INTEGRATION: APPLICATIONS AND EXAMPLES

5.1 Introduction

Examples of key knowledge and practice have been selected, mainly from Australia and New Zealand, which illustrate the integration of asset management and Safe System in response to the requirements and purpose of the proposed framework (Table 4.1). The examples concentrate on IAM Phase 1 to 4. They are identified as being applicable to different contexts, e.g. maintenance and operations, brownfield, or greenfield. In some cases they apply to all three.

The examples aim to address the questions and issues which formed the basis for this Project, with an emphasis on what can asset managers do to embed a Safe System philosophy within asset management, and how this might impact what they do in terms of new processes, and issues. They are accompanied by take home messages, surrounding the lead question of:

> What does the introduction of the Safe System philosophy mean for asset managers?

A number of cross-cutting issues which are relevant to a number of phases are assigned to the one most suited to their initial consideration, e.g. legal implications are addressed in Phase 1 since they are fundamental to community and stakeholder requirements, whereas asset creep is addressed in Phase 3 where the initial and whole-of-life-cycle costs of various treatments are considered.

5.2 Phase 1: Setting Policy Objectives

Phase 1 requires:

- the existence of a Safe System policy with clear priority actions/strategies and quantitative, time-bound targets (reduction in FSI with realistic interim 3–5 year targets) and associated resources which provide a basis for AM leverage/influence
- the policy (or strategy) accounts for contributions by different stakeholders/players, and commitments to its success are widely publicised, and responsibilities are documented in a Corporate AM/SS accountability framework.

The Australian *National Road Safety Strategy* (NRSS) includes priority actions and quantitative targets in terms of reduction in FSI, and similar targets exist in state and territory strategies, and in New Zealand's strategy. The aim is for a 30% to 40% reduction in FSI by around 2020, with improved infrastructure and reductions in speed expected to contribute around half of the reduction. A number of road agencies have also set interim targets, these being largely proportional to the 2020 target.

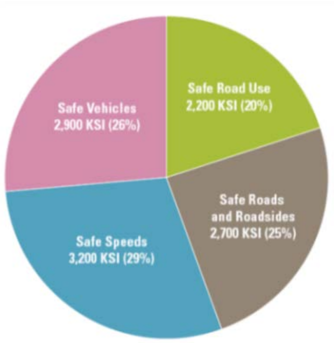
The NRSS also requires road agencies to take responsibility for helping to reduce road crashes in a proactive manner. This is consistent with current guidance on asset management and civil liability (Austroads 2012a) where aiming to prevent incidents occurring on the network through the development and consistent implementation of a sound, effective asset management system, elements of which are continually improved, should make a significant contribution to road agencies achieving positive road safety outcomes and ultimately reducing the number of, and vulnerability to civil claims.

The WA Road Safety Strategy: Towards Zero (Office of Road Safety 2008) is one example of how states and territories are approaching the challenge with Safe System at its core (Table 5.1). It accounts for contributions by different players and commitments to its success and is widely publicised. Main Roads WA has also created a strategy and policy statement, with responsibilities documented in an action plan (MRWA 2011b). WA Local Government has also developed its own response and actions, with these stated in budget submissions (WALGA 2012). These strategies rely on the strong link between the types of intervention and their effectiveness on crash reduction. This is now well documented at a strategic level based on the post evaluation of road crash treatment programs (BTE 2001, RSCWA 2003), and research funded by Austroads and other bodies, e.g. Austroads (2010a).

Table 5.1: Example state and local government strategies

WA State Strategy: Towards Zero (ORS 2008)

Western Australia's road safety strategy, 'Towards Zero', is aiming to deliver a more forgiving road transport system, underpinned by the 'Safe System' approach. The target is to reduce the number of persons killed or seriously injured (FSI) by some 11 000 over a ten year period to 2020, which corresponds to a reduction of 40% on 2009 levels. Improved infrastructure, including roadways and roadsides, is expected to deliver approximately 1/4 of this reduction; and therefore a concerted effort is required to achieve this result. Safe speeds are also expected to make a substantial contribution.



Main Roads WA Road Safety Strategy, 2011–15: The Road Towards Zero (MRWA 2011b)

Main Roads has stated in its strategy that in contributing to the state objectives, it will:

- deliver a safe world class road system
- embed the 'Safe System' approach into the organisation and road sector
- provide assurance to government and community that it is achieving results.

It requires a focus on cultural change: 'To change thinking, practice and behaviour – to let staff imagine all things possible – to build, maintain and operate an inherently safe road system'.

Four areas of focus have been identified to achieve this, each with action plans, in Governance, Safe System Procedures, Practices and Programs, Research and Knowledge Sharing and Capability and Skills.

It is recognised that the implementation of priority actions will take time, and therefore the following three effective and recognised policy initiatives will be implemented immediately:

- adopt a minimum standard of 1 m sealed shoulders and audible edge lines on all new Main Roads projects and upgrades (where appropriate) – this forms the foundation of a move towards providing a Safe System network
- accept requests to reduce speeds, by 10 km/h, in any high pedestrian areas (such as shopping precincts) where there is community support
- adopt the practice of reviewing all major projects during design and construction stages against the Safe Systems principles – this will build Safe Systems knowledge amongst Main Roads project managers and deliver a safer road system for the community.

WA Local Government Association Strategy and Budget Commitments (WALGA 2012)

Local Governments manage 72% of the WA road network (by length) and 67% of crashes occur on the local road network. Consequently local roads must be included in any strategic program to address the safe roads and roadsides principle within the Towards Zero road safety strategy. A 'Safer Local Roads' program implemented in conjunction with the Safer Roads program delivered by Main Roads WA across state roads was seen as the best solution, and was embodied in WALGA's adoption of two new principles in its submission for the State Road Funds to Local Government Agreement 2010–11 to 2014–15 and in its State Budget Submission 2012–13:

- developing and applying good asset management practice in maintaining the LG road network
- promoting a 'Safe System' approach in managing the LG road infrastructure, comprising:
  - Program 1: Run-off-road regional and remote crashes project.
  - Program 2: Urban intersection crashes project.

Source: Adapted from references for each example.

Whilst policies and strategies are now widely established, translating these into actions needs significant resources. Few published studies address this key issue, yet it is fundamental. The danger is unfunded policies will not achieve the goals which have been set.

Such considerations have been a focus for a number of audits of road agencies in the general area of road management, though not specifically crash reduction, and in studies of funding agreements.

However, two recent studies, comprising an independent audit of the performance of state roads in WA, and a study for the WALGA as part of the Review of State Funds to Local Government Funding Agreement, provide examples. The analysis is summarised in Table 5.2 and employed a strategic, top-down approach to provide an estimate of investment needs against what was considered to be stated objectives. The two studies were undertaken without the benefit of Safe System treatments, and therefore illustrate the scale of funding needs using traditional treatments including road improvements. As illustrated later (Section 5.4.2 and 5.4.3), considerable evidence now exists on the performance of Safe System treatments and these have been evaluated at a program level. It is important that this information is employed in future to refine policy, with funding implications well understood from the start. The need for such feedback is also consistent with the AM framework and demonstrates the iterative nature of policy, strategy and program development.

Phase 1: Take home messages for asset managers

- The existence of a comprehensive and well communicated policy provides a clear basis for action covering all applications and requires asset management and safety objectives to be considered together from the outset.
- Asset managers should seek to understand policy objectives and drivers and use them as a basis for strategy, program and project development and implementation.
- Feedback from later phases is essential so that policies are refined and costed in line with performance evidence. Asset managers and other disciplines should seek to facilitate effective feedback and employ the latest knowledge to deliver policy more cost-effectively, and deliver greater benefits.
- With the emergence of the Safe System as a foundation to road safety strategies, it is considered reasonable to assume that a defence strategy against future claims should not alter drastically, whether the Safe System is brought into consideration during the proceedings or not, noting that:
  - Road agencies are unlikely to be exposed to additional risk if they adopt the Safe System approach, it could arguably reduce.
  - There is not an excuse for inaction, since it is anticipated that the adoption and demonstration of best practice will be considered by legal authorities.

Table 5.2: Possible funding needs

Audit of the performance of state roads in WA

This was undertaken as an independent assessment of the condition and funding gap for the state road network, but it could as easily have been done as part of a proactive asset management program to assess how best to manage configuration deficiencies and help address crash reduction targets.

It involved applying established business rules on desirable seal widths to the available road inventory data. Crash reductions were estimated based on research findings which showed that when funding is targeted at specific road safety projects and programs it can be expected to save 1.5 lives a year for every (additional) $10 million spent for the next 20 years (RSCWA 2003), and general road improvements can reduce fatalities by 2 lives per annum per $100 million invested (BTE 2001).

Based on an assessed backlog affecting approximately 20% of the network, and on the assumption that this is progressively removed through capital investment, between 20 and 30 lives (or 100 to 180 FSI) could be saved each year depending on the balance of investment in targeted and general improvements. In this example, the mix was varied between 35:65 and 65:35, with corresponding BCRs attributable solely to crash cost savings of 2.3 and 4 respectively.

Whilst these figures are considerably less than the BCR of 14 at a discount rate of 5% reported from the Federal Blackspot Study (BTE 2001)[9], the results are significant given the mix of locations involved, being primarily mid-blocks. The BCRs quoted are also likely to be an underestimate as the general improvements would be expected to reduce shoulder maintenance costs, and possibly reduce travel times.

Funding needs for local roads in WA

In aiming to support its second new principle of providing safer road infrastructure, which aligns with the commitment by the state to 'Towards Zero' (ORS 2008), the Western Australia Local Government Association investigated the potential contribution from infrastructure improvements, and the associated funding implications.

The analysis of infrastructure-related investment needs involved the following:

- Determination of the number and distribution of fatal and serious crashes by jurisdiction (MRWA or LG managed) and location considering:
  - intersection type (State-State, State-Local, Local-Local, etc.)
  - mid-block locations (State or Local).
- Accounting for the local roads' share of state-wide estimates, estimated to be approximately 1700 FSI per year. Of this, approximately one-third, or 550 FSI, was attributed to Local Roads of Regional Significance (LRRS), these being identified as the priority for funding under the State Road Funds to Local Government Agreement.
- Calculating annual investment needs based on achieving target FSI reductions during the 12 year plan by either a targeted reduction strategy (assuming for simplicity that intersection crashes represent 'blackspots') or a general improvement strategy. This provided a lower and upper estimate of investment needs, by employing the results of national and state studies which suggest an investment effectiveness of $0.45m per FSI for targeted improvements, and $6.6m per FSI for general improvements. This assumes that a treatment remains effective for up to 20 years (ORS 2003), which is well beyond the plan period. Where funds are solely employed to target high risk locations, the annual needs varied between $8m and $24m based on the full local government managed network, and the LRRS network respectively. Considerably greater funds would be required if the crash reduction targets were sought through a general improvement approach. A mix of the two treatment approaches is the most likely response, but this will have cost implications. However, if safety-related treatments are timed to coincide with other complementary treatments, e.g. pavement resurfacing, rehabilitation, etc. as part of an overall renewal strategy, the total sum of benefits would most likely be considerably greater as illustrated by the case studies quoted above. Program costs are also likely to reduce if a Safe System approach was adopted, since these are likely to be more cost effective per crash than a general improvement approach, but this needs to be investigated.

[9] The evaluation of the Federal Blackspot Program has recently been the subject of a further evaluation and a lower BCR has been reported (BITRE 2012), with values of 7.7 at a 3% discount rate and 4.7 at a 7% discount rate based on estimated casualty crashes avoided and project costs. Crash reduction rates were however reported to be broadly similar to those in Table 5.7.

5.3 Phase 2: Asset Strategies

Phase 2 requires:

- a network vision which articulates how the network will be managed and developed
- a clearly defined hierarchy, covering role and function, and LOS
- a balanced strategy which supports the policy and network vision with overall targets (in Phase 1) disaggregated considering risk and equity
- evidence-based guidelines (for both brownfield and greenfield sites) to inform data collection, risk assessment, treatment selection and prioritisation, including non-build solutions
- that the proposed suite of solutions has been communicated to and accepted as being workable by all stakeholders and contributors and benefits are well understood.

International examples are available and show the components mentioned above and show how the increased introduction of road infrastructure features contribute to the aim of minimising harm. These are also becoming more widespread in Australia and New Zealand. They demonstrate how agencies have considered what a Safe System might look like, or their intent through the design and implementation of programs.

MRWA has investigated the attributes of a Safe System as a basis for future asset management, and the key attributes of what a Safe System may constitute based on its work is shown in Table 5.3 (MRWA 2011a). This provides a basis for a gap analysis of current infrastructure at a strategic level, and extends the classification used for assessing the adequacy of road widths in relation to road use, e.g. as contained in the National Transport Commission *Performance Based Standards Network Classification Guidelines* (NTC 2007), and the rules established for road asset preservation. Wider introduction will progressively change the road environment from that to which many drivers have become familiar.

Whereas the progressive introduction of a Safe System is now widespread, a balanced strategy using the Safe System philosophy within asset management which supports the policy and network vision is essential, including other targets such as route security, considering risk and equity.

The NSW *Brownfields Road Design Guide* (RTA 2007), which has been in use since 2007 and is currently under revision, is a further example where the balance of treatments has been demonstrated and the introduction of a combination of supporting treatments and primary treatments has occurred across the network.

The NZ *High-Risk Rural Roads Guide* (NZTA 2011) is a more recent example which addresses safer roads and roadsides and to a lesser degree safe speed by applying Safe System principles, through:

- identification of key crash issues
- tools to help identify and analyse high-risk rural roads
- a range of countermeasures for key crash types to help develop best-value treatments
- guidance for developing, prioritising and funding road safety infrastructure and speed management programs
- references to further tools and resources to evaluate implemented countermeasures.

Table 5.3: Example attributes of a Safe System

	Freeway/ major highway	Urban roads intermediate speeds (< 80 km/h)	Rural high speed and high traffic AADT > 1000	Rural high speed and medium traffic AADT 500–1000	Rural high speed and low traffic < AADT 500
Roadside elements					
Street lighting	✓	✓	At intersections	As required	✗
Clear zone	n.a. as barriers are required	Reduced clear zone where practical	n.a. as barriers are required	Full clear zone where practical or barriers where justified	Reduced clear zone
Barriers (long lengths)	✓	Consider use of crashworthy protective devices	✓	Where appropriate	Isolated locations
Crashworthy roadside furniture	✓	✓	✓	✓	✓
Reduced speed zone	Urban intersections	✓	Where appropriate	Only in conjunction with ITS solutions	✗
Real time risk reduction	✓	Where appropriate			
Intersections					
Major intersection type	Ideally roundabouts if low % trucks and few large vehicles			Type fit for purpose	Type fit for purpose
Turn pockets to reduce conflicts	✓	✓	✓	On as required basis	On as required basis
Cross-section					
Median/separation	n.a. or for future flexibility e.g. future rapid transit or additional capacity	✓	Sections with high number of head-on crashes, or where duplication is appropriate	As required	
Lane width	As per standards	As per standards	Possible use of narrow lanes to provide extra shoulder width and to change driver behaviour.		
Sealed shoulders	✓	n.a.	2.0 m	> 1 m sealed shoulders	> 0.5 m
Line marking	Standard line marking	Standard line marking	Audible – edge and centre	Audible – edge and centre	Edge lines throughout and audible lines at isolated locations
Vulnerable users					
Motorcyclists	Entry and exit ramps may require some treatment	n.a.	n.a.	Special treatments where heavily used by recreational motorcyclists	
Pedestrians	Grade separation facilities	Appropriate facilities in combination with safe speeds	Appropriate facilities in combination with safe speeds	As required	No treatments
Cyclists	n.a. other than at intersections	Appropriate width bike lane or wide kerbside lane	Appropriate sealed shoulder width	As required	No treatments

Source: Adapted from MRWA (2011a).

In yet another example (Table 5.4), the composition and size of VicRoads Safer Road Infrastructure Program (SRIP) is illustrated. The program is based on a Safe System approach. The SRIP has been subject to three post-evaluation studies, with the independent evaluation of the program undertaken by Monash University's Accident Research Centre (2011a, 2011b, 2011c). The results of these have demonstrated the effectiveness of the program in reducing serious injury and casualty crashes, with slightly greater crash reductions being observed for intersection treatments than for run-off-road treatments. The cost-effectiveness of different treatments, expressed in dollars per serious injury saved, or casualty injury saved, has been determined. Significant benefit cost ratios have been estimated for the life of the treatments with these evaluated on the basis of lost output (Austroads 2012b). Differences between the crash reduction factors applied during program development and those observed have also been identified, and will be applied in updating current guidelines.

In an example which illustrates a non-build solution and engaging the support of the community and enforcement agencies, reduced speed limits have been introduced on local roads on the Mornington Peninsula, Victoria (Table 5.5). This is a good illustration of the cooperation which can be mobilised to provide additional leverage.

Further information on how specific Australian states have adopted Safe System principles is reported in Hall (2011) and Mooren et al (2011). These illustrate that a range of approaches exist, with early successes in a number of cases but with the recognition that the approaches are still developing and full community and stakeholder support is yet to be achieved.

Phase 2: Take home messages for asset managers

- Key attributes should be defined for different roads, covering brownfield sites and greenfield sites, including new roads or major upgrades. The attributes should take account of road use and risk to help inform the development of asset strategies, and be applied as part of the gap analysis as input to program development.
- Recent findings from the post-evaluation of Safe System treatments at a program level provide a sounder basis for informing strategy development, and program composition. They demonstrate significant economic benefits, and provide economic justification for adopting primary Safe System treatments particularly for more highly trafficked roads. They should be applied by asset managers and others to specify infrastructure requirements.
- Speed management is being adopted as a measure in lower volume rural roads, in addition to its more widespread use in urban and sub-urban areas. It offers a cost-effective alternative in many circumstances.
- Practitioners have defined and agreed some components of Safe System relevant to Strategy development including:
  - Safe System is a network wide approach.
  - An incremental approach to reducing FSI and applying Safe System is appropriate.
  - It is appropriate for asset managers to continue to balance Safe System requirements against and with other community requirements.

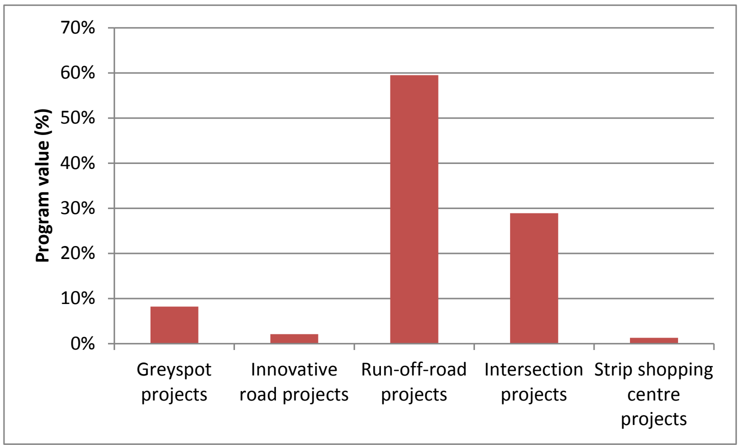
Table 5.4: Scope and effectiveness of a crash reduction program based on Safe System principles

Victoria's Safer Road Infrastructure Program (SRIP) was established to try and reduce the number and severity of crashes along roads with a relatively high number of serious casualty crashes. The program commenced in 2008 and will run until 2017. Funding of $650m is primarily provided by the Transport Accident Commission, and guidelines have been developed for the development of intersection and run-off-road projects, which comprise the most common fatal and serious injury crashes.

There are six types of project which are funded by the program:

- Greyspot projects, in areas where a safety risk has been identified, which do not meet the requirements for a traditional black-spot program. Examples of treatments are pavement widening, installing street lighting, improved delineation, vehicle activated signs, installing turning lanes and hazard removal.
- Innovative road projects, where new treatments are used to solve specific problems. Examples are changes to traffic signal sequencing, installing traffic signals at roundabouts, use of retro-reflective bands on snow poles and installing virtual speed bumps.
- Run-off-road projects, targets sections of road where there is a high risk of run-off-road crashes. Examples of treatments are shoulder sealing, installing safety barriers, line marking and audio tactile edge lines, improved skid resistance and hazard removal (e.g. trees and telegraph poles).
- Intersection projects, target those locations with high crash history or considered to be a safety risk. Examples are traffic signal upgrades, vehicle activated signs, static signs, line marking, shoulder sealing, roundabouts and skid resistance.
- Strip shopping centre projects, address the risks associated with the high numbers of pedestrians with speed limits reduced to 40 km/h.
- Motorcycle blackspot project, target sections of road which are a particular risk for motorcyclists, either through a high crash history, or large volumes of motorcycle traffic. The motorcycle blackspot projects are funded separately from the Motorcycle Safety Levy.

The percentage distribution of the total value of completed, ongoing and planned projects is shown below. Whilst not explicitly stated, the largest allocations reflect the representation of fatal and serious injury crashes, with run-off-road crashes accounting for 41% of fatal and 29% of serious injury crashes state-wide, and intersections accounting for 28% of fatal and 39% of serious injury crashes state-wide.



Program effectiveness has been evaluated on three occasions, and the results are shown below. The cost-effectiveness of the program lies between that of a blackspot program, and a general road improvements program, being approximately three times more effective than the latter, but only 1/3rd as effective as the former.

Phase	Number of sites included in evaluation	Casualty crash reduction	Serious injury crash reduction	Benefit cost ratio
SRIP 1	109	24%	31%	2.1
SRIP 2	245	33%	44%	3.6 (no change in rate) 4.5 (crash rate increases with population growth)
SRIP 3 (Preliminary)	279	31%	Not reported	2.4

Source: Adapted from VicRoads SRIP, http://www.vicroads.vic.gov.au/Home/SafetyAndRules/SaferRoads/BuildingSaferRoads.htm and MUARC (2011a, 2011b and 2011c).

Table 5.5: Communications – Safe speeds on local roads

Over the past five years, 268 casualty crashes have been recorded in residential areas in Mornington Peninsula Shire (MPS), a high number of which involve pedestrians and cyclists. In the same period, 165 casualty crashes have been recorded on local rural roads. Community concern has also been raised regarding safety on residential and rural roads. The Peninsula Safer Speeds project has been developed to reduce the crash risk and casualties in addition to other current safety programs.
Based on the well-established finding that even small decreases in speed can result in substantial safety benefits, the Shire is trialling lower speeds on a selection of urban streets and rural roads. High crash risk areas are being targeted.
New 40 km/h Area signs have been installed, and 80 km/h and 90 km/h speed zones have been installed on 15 local rural roads. The lower speed limits on rural roads in particular reflect the lower design standard of these roads.
As part of a community engagement strategy that complemented the reduction in speed limits, information material was produced outlining the changes. This included distributing leaflets to residents; community consultation events (including an information van at the local market and senior citizens centre); and production of a Facebook page. Community support for the change is very high, with 80% of residents being supportive of the initiative prior to implementation. Community response to this change is being monitored, as is the effect on speed.
Further information can be found at the Shire website: http://www.mornpen.vic.gov.au/Page/page.asp?Page_Id=1397&h=0

5.4 Phases 3 and 4: Investment Program and Identify Asset Requirements

These phases are also known as Tactical Planning and Programming, and Project Development, and to be effective require:

- time-series data at a sub-network, route and link level to
  - assess asset related risks
  - quantify the occurrence and density of crashes, and crash types
  - assess crash trends (all and FSI), and any associations with road use
- knowledge of the crash performance of different (primary and supporting) treatments
- comprehensive cost data
- appropriate processes, systems and tools
- a feedback loop.

5.4.1 Availability and Use of Infrastructure Related Data and Crash Data

Perhaps the most significant change in the last decade or so has been the increase in the availability and quality of infrastructure-related data, with this extending from road surface, geometry and inventory related information to the recording of roadside attributes which contribute to safety risks. This has benefited from the use of modern technologies, including vehicle mounted systems fitted with multiple high quality cameras, both still and video, which operate at traffic speed. Devices which can record offsets to hazards are also increasingly available.

Crash statistics, and location and crash evaluation data recorded by the Police and specialist accident investigation units and from hospitals can be examined to investigate crash causes, including the road user movements associated with specific crashes. This offers a powerful set of information to inform treatment strategies and programs to help reduce the occurrence and severity of crashes.

The combination of crash and infrastructure data provides a powerful basis for analysing risks, various associations and trends when used along with crash risk assessment and management tools, such as KiwiRAP and ANRAM (Section 3.4.4).

This data can be employed to determine what maintenance or safety improvement works need to be undertaken, with the network and specific locations assessed against prescribed criteria to determine ability to meet current and future purposes and functional requirements. Gaps between the criteria and the state of the asset can then be used to drive program development.

Two types of gaps can be identified:

- performance gaps (e.g. outcome based statistics such as road crash toll figures)
- asset gaps (configuration and condition defects).

There are many possible parameters and criteria that can be assessed, such as criteria relating to asset types (e.g. seal condition), parameters relating to the road environment (e.g. sight distances), and users (e.g. cyclists prefer wide shoulders). Under a Safe System new criteria are used that build upon crash outcomes and human tolerance. This allows asset managers to identify locations and/or asset types where road user mistakes lead to, or may lead to FSI outcomes.

Much of the information required for gap analysis exists within a road agency or is part of an ongoing monitoring program. Some will need reconfiguring, and additional information may be needed. Newer safety assets also often come with limited lifecycle information making it difficult to report on the current status of the asset and define criteria against which to assess them.

In order to understand the current status and performance of the road network in terms of Safe System, asset managers also need to understand what a Safe System looks like in relation to the physical characteristics they can measure, and possible infrastructure requirements, as follows:

- Relevant physical characteristics are defined in Appendix A based on the ANRAM requirements, which in turn employ those of iRAP v3.
- Example desirable infrastructure attributes and requirements were addressed in Section 5.3 and illustrated in Table 5.3.

In summary, quality data is fundamental to the asset management gap analysis process and contributes to a feasible method of applying and implementing the Safe System philosophy within asset management in a robust and systematic manner.

5.4.2 Safety Performance of Road Infrastructure and Mitigation Measures

Traditionally roads were designed based on traffic needs and safety treatments were installed to meet the standards of the day. A move towards Safe System practice being integrated into asset management requires safety to be considered at all stages of the process, from planning to design, monitoring and maintenance.

The ability to inform choices has developed considerably, and in terms of safety performance has evolved from general relationships for different road configurations, such as the crash rates developed for different Model Road States (MRS) described in Austroads (2001) and illustrated in Table 5.6. These have been incorporated in many of the cost benefit analysis tools employed by road agencies, and which are now being updated to include more recent and more detailed models.

Table 5.6: Estimation of mid-block crash rates based on the Model Road State concept

MRS based concept

The concept of the Model Road State (MRS) described in Austroads (2001) can be used to help determine the crash risk of a road and the effect of adding certain safety treatments. It employs the following equation to determine an estimated crash rate.

ACR = KMRS * KHA * ABCR

where:

ACR = predicted casualty crash rate (per 100 million VKT)

ABCR = base crash rate (25 casualty crashes per 100 million VKT for a rural road with 7 m seal and a speed zone of 90 km/h or less)

KMRS = model road state factor for no curves

KHA = modification factor for horizontal alignment

MRS-based crash rates for a selection of road configurations.

Model Road State	No. of crashes by severity type (crashes per 100 million vehicle km travelled)			
	Fatal	Personal injury	Damage only	All
MRS04 – Gravel > 4.5 m	1.75	33.25	91.00	126.00
MRS05 – Sealed <= 4.5 m	1.50	28.50	74.00	104.00
MRS08 – Undivided 5.81–6.4 m	1.63	30.88	54.50	87.00
MRS09 – Undivided 6.41–7.0 m	1.25	23.75	45.00	70.00
MRS10 – Undivided 7.01–7.6 m	1.13	21.38	35.50	58.00
MRS11 – Undivided 7.61–8.2 m	1.06	20.19	30.75	52.00
MRS12 – Undivided 8.21–8.8 m	1.00	19.00	29.00	49.00
MRS17 – Undivided >= 13.7 m four lane	1.06	20.19	33.75	55.00
MRS18 – Divided two lane per c/w <= 7.6 m	0.60	19.40	32.00	52.00
MRS24 – Freeway two lane per c/w <= 9.4 m	0.40	5.35	14.25	20.00

Other considerations

For general application, the MRS based system also requires the split between fatal and serious injuries to be determined, and therefore a typical fatal and serious index needs to be considered. It also requires separation of personal injury crashes into serious and minor. Typically, the ratio between each severity of crash is approximately 10, but more specific values have been determined from more recent research (Austroads 2010a).

Source: Adapted from Austroads (2001).

Advances in the last decade or so now provide the means of determining the crash risk of a road and the effect of adding specific safety treatments, this being essential if advantage is to be taken of the Safe System principles. It allows consideration of the performance of Primary or Supporting treatments (Section 2.2), and combination treatments and therefore informs treatment strategies which help minimise death and serious injury as well as those that assist in delivering safety improvements but do so indirectly.

Crash reductions of a selection of safety treatments in addressing particular crash types are shown in Table 5.7. They offer the advantage that they can be applied in a more targeted manner to support best value solutions. A more comprehensive list is provided in Austroads (2012a).

Table 5.7: Reduction in casualty crash rates for a selection of safety treatments

Primary treatments	Head-on crashes	Run-off-road crashes	Intersection crashes
Removal of roadside objects		25–40%	
Roadside barriers		25–40%	
Roundabouts			60+%
Divided roads and/or median barriers	40–60%	40–60%	
Intersection-grade separation			40–60%
Supporting treatments			
Road signs and delineation	25–40%	25–40%	25–40%
Shoulder sealing	25–40%	25–40%	
Rumble strips	10–25%	10–25%	
Central median hatching	10–25%		

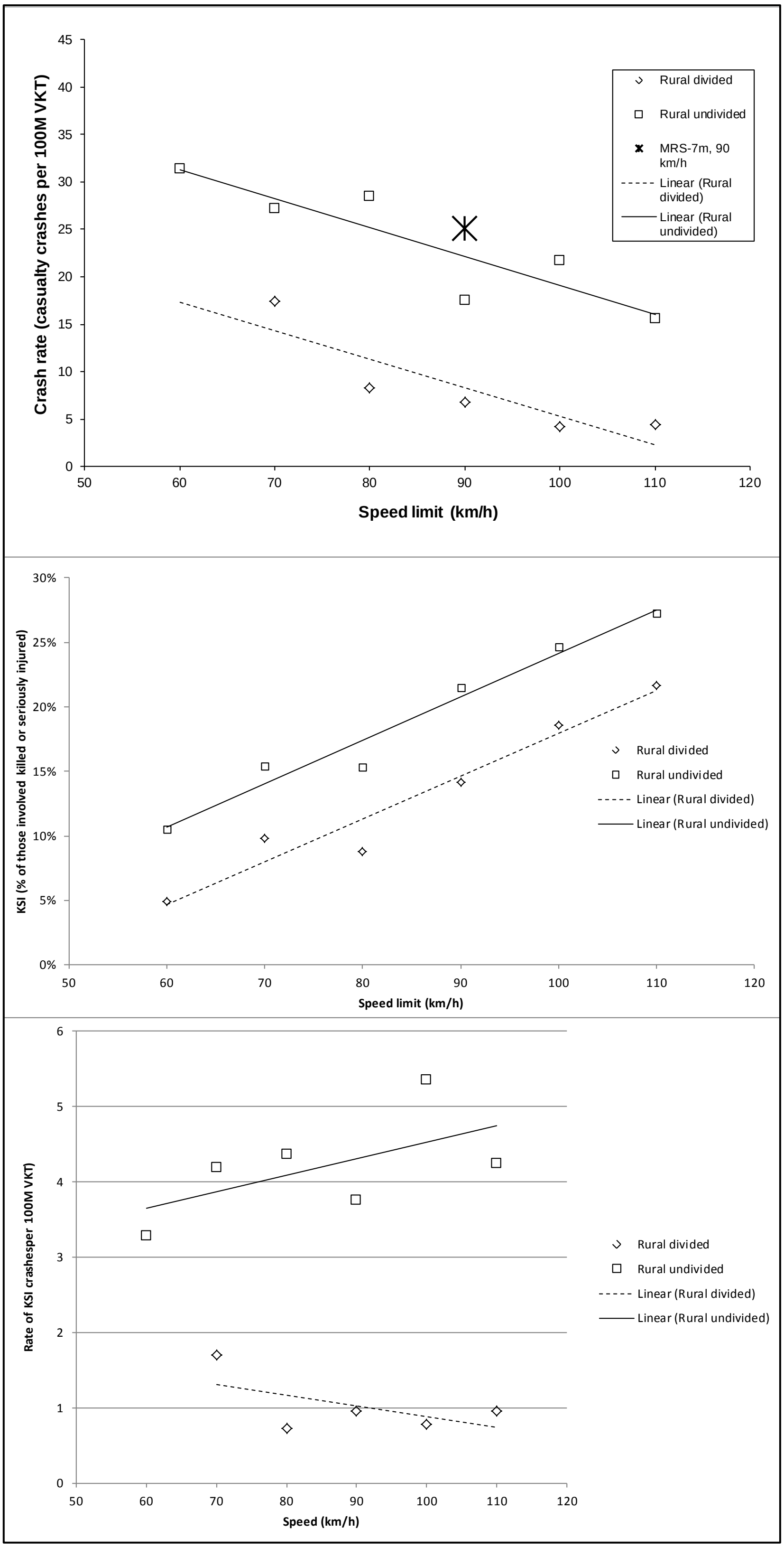
Source: Adapted from KiwiRAP (2010). See full list in Austroads (2012c).

With the aim of a Safe System being to minimise fatal and serious injuries, reporting of crash statistics requires total casualty crashes to be reported as FSI, so that any tools used to aid program development can estimate the effect on FSI.

An example drawn from recent research findings (Austroads 2010a) on the relationship between all crashes and speed limit and the FSI index is shown in Figure 5.1. Also shown is a relationship between FSI and speed limit for rural undivided and rural divided roads. It is apparent that the relationship between speed, infrastructure and crash risk is many faceted, but a decrease in speed generally reduces the risk of being killed or seriously injured. Further, the divided road example illustrates that roads with a higher design standard (e.g. with larger clear zones, medians, barriers and wider sealed surfaces) can accommodate higher travel speeds/speed limits.

The MRS estimate for a rural 7 m wide road (Table 5.6) is also shown in the uppermost chart in Figure 5.1. The estimate falls close to the recently established relationship, and confirms the reasonableness of the earlier work. This is heartening, as many planning models utilise this approach.

Recent preliminary studies in New Zealand (NZTA 2010) have also established a relationship between crashes on rural two-lane roads and key road features. The study was initiated in recognition of the fact that historic crash patterns are not always sufficient to enable a suitable diagnosis of the safety deficiencies of sections of the NZ rural road network, much of which is low volume, and where the scarcity of crashes may mask the considerable potential for safety improvements.



Source: Adapted from Austroads (2010a).

Figure 5.1: Relationships between speed limit and crashes for rural roads

The overall purpose of the NZ research was to quantify the impact of all key road features on the safety of two-lane rural roads, and understand/quantify any interaction between these variables, thus extending the detail included in previous studies of different Model Road States (Austroads 2001). Preliminary relationships were determined based on a set of 28 predictor variables, with five variables comprising the two-way AADT, distance to any non-traversable hazard (e.g. row of trees or deep ditch), absolute gradient, SCRIM value and the percentage reduction in the curve-negotiation speed of the section being the most significant. The model results were evidence of the important influence that the roadside environment and road geometry have on predicted crash rate. However, most secondary variables (except the SCRIM coefficient) were deemed only to have a subtle influence. No doubt many of the results were sensitive to the small size of the data set and, as a pilot for a planned wider study; but the research has been successful in identifying the key variables and data collection issues that will be critical to progress the main research project.

Evidence reported to date has generally demonstrated the benefits of installing new safety features where there were none before. Research has also confirmed the obvious causal linkage between the condition of the road, its related assets and crash likelihood and/or consequence. Examples of this include condition attributes such as the skid resistance of road surfaces, the reflectivity of line markings, and the frangibility of sign posts. Whilst these treatments are not classified as primary Safe System treatments, they can have a significant impact on the likelihood of crash events, a proportion of which will have a FSI outcome where crash protection is limited and hazards exist.

Available treatments to restore asset condition and contribute safety benefits are documented by Austroads (2010b) and include:

- routine or general maintenance works through, for example:
  - clearing vegetation to restore sight lines, and improve the visibility of road signs
  - cleaning and replacement of retro-reflective pavement markers
  - the removal of loose gravel, or diesel from roads to improve skid resistance
  - cleaning lichen or dirt from edge marker posts to improve conspicuity
- periodic or renewal treatments through, for example:
  - improved skid resistance of road surfaces, by selecting an aggregate for use in sprayed seals that retains adequate skid resistance properties over the life of the seal
  - improved line reflectivity and delineation
  - replacement of deteriorated or obsolescent barriers
  - reduced rutting or roughness.

An extensive body of knowledge and tools exist to support the above requirements, and examples of these are included in Table 5.8 and Table 5.9 and comprise:

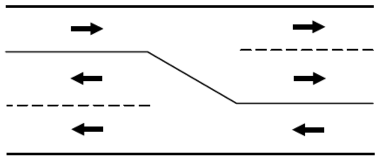
- primary treatments such as wire rope steel barrier, used to mitigate head-on and run-off-road crashes (Table 5.8)
- supporting treatments such as the use of improved surfacing aggregates and better road markings (Table 5.9).

An interesting finding is **in many cases cost savings occur from using new or innovative solutions, although the initial investment will be required if subsequent savings are to be made**. This is clearly demonstrated in relation to road surface treatments and line markings. It includes net savings to the road agency and crash cost/social savings. This is an important conclusion as it means there is significant potential for a win-win, and therefore technical efficiencies are possible.

Table 5.8: The use and performance of wire rope barriers

The Swedish experience with wire rope barrier – 2+1

Since 1998, Sweden has retrofitted over 2000 km of roads with the '2+1' median treatment. This involves the fitting of wire rope barrier to paved two-lane roads that are 12–13 m wide. One continuous lane is provided in each direction, while a central lane alternates allowing safe overtaking for a limited length of road in one direction, and then the other. As well as allowing vehicles to safely pass slower vehicles, the use of a central wire rope barrier effectively separates the flow of traffic preventing head-on crashes from occurring.



2+1 configuration

The system has produced large savings in crashes in Sweden, with a 45–50% reduction in those killed or seriously injured on their two-lane restricted access roads (semi-motorway), and a reduction in fatalities only of up to 90%.

It is important to note that profiles for Australian and New Zealand roads are typically less than the 13 m found on these types of roads in Sweden, and trial projects have been implemented to retrofit existing 9 m roads to a 1+1 design. These are also separated by wire rope barrier, and include provision of overtaking lanes with intervals of between 4 and 10 km. These trials are being assessed, and although problems have been identified (including issues with vehicle breakdowns) they also show great potential for serious crash reduction.

Perhaps of greatest interest from this case study is the approach that has been used in Sweden to addressing a key crash problem. Analysis has been conducted to assess the major crash problem on these rural roads, and large scale trials have been undertaken to test solutions. Although 2+1 systems may not be as suitable for Australasian roads, this evidence based-approach to addressing the rural crash problem could also be used here.

The Coast Road median barrier (State Highway 1, New Zealand)

In the seven years from 1994 to 2000 there were 21 head-on crashes on the Coast Road section of State Highway 1 north of Wellington. Transit New Zealand responded with a series of control measures that successfully eliminated fatal crashes for two years.

In 2004 the occurrence of two serious crashes reignited the community's call for further action. Transit responded quickly, tackling the challenging physical environment to install a 700 m long median barrier on the narrow carriageway.

Physical works on the median barrier began on 26 October 2004. On 22 November, the NZ$1 million project was completed. In total, from planning through to completion, the Coast Road median project took little more than three months. Following the outstanding success of the median barrier, it was extended in length to 3.4 kilometres in 2007.

Crash records for the total 3.4 kilometres length over the five year period prior to the initial median barrier installation (between 2000 and 2004) indicate that there were seven fatal crashes, three serious injury crashes, five minor injury crashes and 17 non-injury crashes. Over the following five year period from 2005 to 2009 there was one serious injury crash, four minor injury crashes and 33 non-injury crashes. The serious injury crash in the last five year period happened in 2008 and involved a cyclist that was hit from behind by a car.

Transit also installed video cameras to monitor driver behaviour before, during and after installation of the barrier. Since installation of the barrier, there had been 59 recorded strikes on the barrier as of January 2010. Driver behaviour and confidence has improved. The surveillance footage showed drivers are positioning themselves more centrally in the lane, giving more separation between opposing vehicles.

Benefits from median barriers in Western Australia

The Mandjoogoordap Drive (formerly named Mandurah Entrance Road) project delivered capital cost savings due to:

- lower earthwork costs as the footprint was narrowed by using a narrower median enabled by the barrier
- less clearing costs due to use of verge barriers
- no additional land take as the improvement fitted within the existing right of way.

Details at http://www.mainroads.wa.gov.au/BuildingRoads/Projects/CompletedProjects/Pages/mandurah.aspx

Source: www.iRAP.org.

Table 5.9: Benefits of improved surface characteristics and line markings

Benefits of high PSV aggregate

Research by VicRoads into skid resistance suggests that sideways force coefficient (SFC) is related to polished stone value (PSV), i.e. the higher the PSV the higher the SFC even though the SFC decreased over time. In further studies at intersections a loss of five points of SFC was recorded due to the increased stress.

The general conclusion from the research was that by using the aggregates available in Victoria it was unlikely to achieve the investigatory levels for intersections for any significant length of time. However, if use is made of the highest readily available PSV aggregates they would remain at a higher SFC over the life of the treatment than lower PSV aggregates. The difference in SFC between the highest and lower PSV aggregates was the difference in PSV, i.e. if a PSV 60 aggregate was used the difference in SFC over the lifetime would be 12 units compared to an alternative aggregate of PSV 48. Even when the PSV 60 aggregate polished to a SFC of 50 it was determined that the PSV 48 aggregate would have polished to an SFC of about 38, i.e. retaining the 12 difference. Related studies also suggested a crash-SFC relationship.

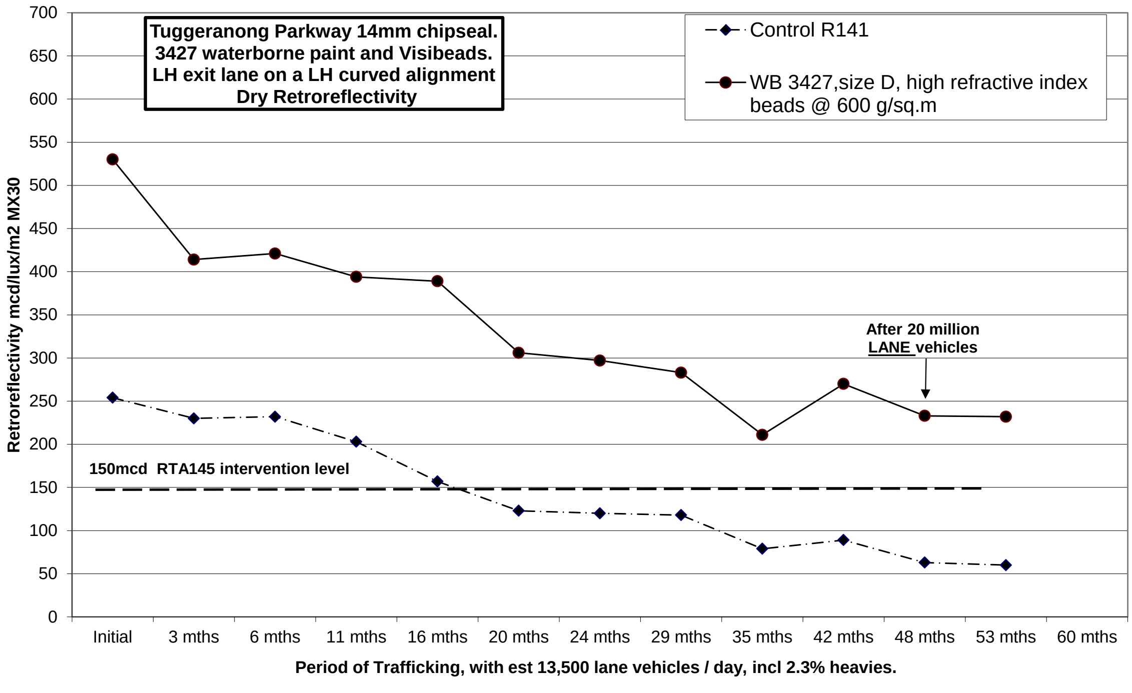
In conclusion, higher PSV aggregates should be used at the most needy locations because they retain a higher SFC than lower PSV aggregates. VicRoads Maintenance Guidelines and specifications were amended, with a crash reduction of 10% to 20% estimated at effectively no extra life cycle cost.

Improved line markings

The Road Safety Risk Manager assumes an 18% reduction in casualty crashes where lines are faded and renewed or added, but what is faded and can line marking influence safety?

Studies in Victoria have shown that 25% of all crashes at a defined black spot location are related to poor line marking. One study (Smadi et al. 2008) suggested a 10% reduction in dusk to dawn crashes for a change in retroreflectivity of 100 to 150 mcd/lx/m^2.

RMS NSW studies have also demonstrated a relationship between retroreflectivity and trafficking, with a life of 48–60 months delivered based on an initial specification of 400 to 500 mcd/lx/m^2, or some 2 to 2.5 times typical lives in Victoria for an additional cost of 20% to 30%.



Source: Based on email on 2 April 2012, Ian Cossens from VicRoads drawing on VicRoads and RMS NSW studies.

In each of the above examples future maintenance has been accounted for in the analysis. This is crucial for the following reasons. Firstly, any life cycle analysis should include all costs, and in a number of cases the wider social benefits (or cost reductions) which are being sought will, in the majority of cases, require additional spending. The need is to estimate the difference in maintenance/operating costs, noting that some treatments will incur a net increase whereas others may be neutral or reduce future costs by delaying the need for re-treatment.

5.4.3 Cost Implications of Safe System Treatments

An increasing body of information now exists on the cost of Safe System treatments, and other crash reduction and safety related treatments. Whereas it is an essential input into program and project development, and evaluation, it should also be used to inform policy and strategy development and ensure target safety-related levels of service are affordable.

Cost information is also essential to inform budgeting, and allows future budget implications to be understood and considered prior to rather than after an investment decision is made.

Asset managers have also been concerned that the adoption of the Safe System implies significant asset creep; representing the risks asset managers face in maintaining an ever increasing asset base within a budget that commonly does not increase in line with the requirements of the widening asset base. Three types of asset creep are recognised (Table 5.10).

Table 5.10: Types of asset creep

Type of asset creep	Description
Expansion of the **quantity** of asset to maintain.	An increase in the amount of existing (well known) asset types. The principal risk asset managers face is finding additional funds for a larger maintenance and operations task. Well known road safety infrastructure types that have been used and maintained for some time will fit this category. The expansion of common Safe System treatments, such as wire rope steel barriers on major roads, will require an increase in funding (Table 5.11).
Expansion and evolution of the assets **performance** and **functionality** to maintain.	An expansion of functional requirements of existing asset types where a change or increase in the functional demand contributes to the assets obsolescence or increases maintenance. The evolution of safety requirements in response to crash research has changed the functional requirements of some asset components, for example the skid resistance of pavement surfacings on top of surface distress, roughness and rutting. Changes in the operating environmental have similar impacts, e.g. traffic increases leading to an increase in incidents and asset damage or a vigorous growing season increasing the amount of sight line vegetation pruning.
Expansion of new and **unknown** asset types.	The implication of introducing a new type of asset to the network that is unfamiliar to the manager responsible for the assets ongoing operation and maintenance. The concern is that asset managers may not know how to or do not have the resources to inspect and maintain these assets. Previously wire rope barriers fell into this area, whereas today new electronic assets could be considered an issue where the asset is a one-off proprietary product, or new generic assets such as solar panels and LED lighting.

Asset creep is not new to asset managers and as such it is not an issue specifically associated with adopting a Safe System. However a Safe System policy could be expected to accelerate this process and significantly increase an asset manager's risk in the short term whilst adjusting to the new asset creep paradigm.

The post evaluation of VicRoads SRIP provides examples of the net economic benefits and the whole-of-life-cycle costs of Safe System treatments (MUARC 2011a, 2011b and 2011c). Indicative costs of initial installation, differential maintenance and operating costs, and renewal are also available from various sources, e.g. VicRoads (2010) and accompanying tools. These have been used along with other available data to demonstrate the cost implications of adopting wire rope safety barrier as a primary treatment along with a sealed shoulder and tactile edge line (Table 5.11) which aim to reduce the likelihood and severity of run-off-road crashes. Such treatments are increasingly common on freeways and arterials.

Table 5.11: Cost implications of wire rope steel barriers and supporting treatments[10]

Whole-of-life-cycle costs

For the SRIP2 program (MUARC 2011b), whole-of-life-cycle capital costs accounted for approximately 99.5% of the total road agency costs of the combined program associated with wire rope safety barrier (WRSB) and shoulder sealing and tactile edge lines. Differential maintenance and operating costs accounted for the remaining 0.5%. The costs are based on a treatment life of an estimated 20 years, and assume:

- The cost of maintaining and renewing a sealed shoulder treatment is the same as that of an unsealed shoulder, and therefore there is no difference in future costs.
- The cost of tactile edge lines is between 5–10% more than plain edge lines, whereas the expected lives are similar.
- Differential maintenance and operating costs are of the order of $1600 per hit, i.e. related to the number of crashes which impact the WRSB.

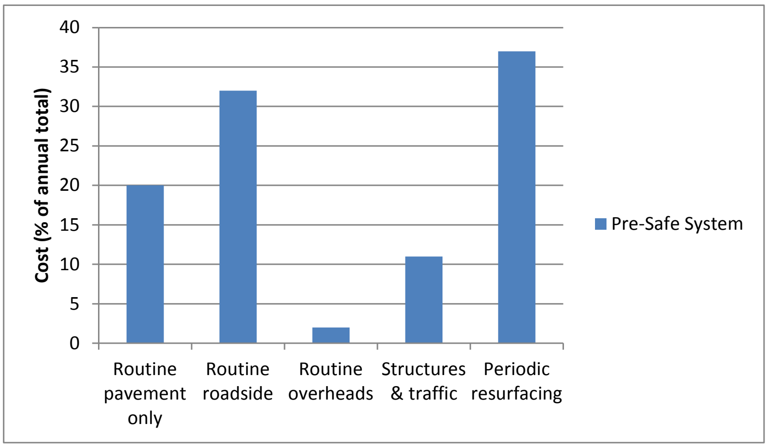
The implication is costs of the initial provision and subsequent renewal to maintain the desirable safety LOS dominate road agency costs.

Costs of initial provision and treatment renewal

- For the WRSB, initial costs are approximately $150 per m, with coverage depending on the specific site, say 50% on both sides of the road.
- Shoulder sealing costs, including preparation, are approximately $30 per m^2 with a life of 20 years, and tactile edge lines are $8000 per km.
- The resulting cost of initial provision is: $150 000 for the WRSB (both sides of road at 50% coverage) + $90 000 for the sealed shoulder (both sides of road with 1.5 m shoulder) + $8000 (tactile edge lines on both sides of road) = $248 000 per km.
- Periodic treatments include retreatment of the tactile edge lines at five year intervals, and repairs to the WRSB following crash damage.
- Provision for renewal is required after 20 years to maintain safety LOS.
- Total annual average costs will be approximately $13 600 per km treated, plus variable differential maintenance and operating cost of WRSB, with the assumption that the extensive use of such treatments will be reflected in the need for a substantial increase in annual funding.

Relation to annual maintenance costs

The distribution of annual routine maintenance and programmed resurfacing maintenance costs for freeways and arterials prior to the widespread adoption of Safe System treatments are shown below, with the annual average cost being in the order of $15 000.



Potential implications for long term budgeting

For the above example, each km of road requiring extensive lengths of the Safe System treatments to substantially mitigate FSI will require both an increase in annual costs, to repair impact damage and inspection costs, and periodic renewal costs. The latter are the most significant, and based on the example shown are estimated to be approximately $9000 per km per year, or an increase in annual costs of approximately 60% per km treated to fully replace the WRSB and resurface the shoulder. Differential maintenance and operating costs in this case are more modest.

Finally, in Victoria, the initial provision of the SRIP Safe System treatments was funded from the State's Transport Accident Commission. It might reasonably be expected that renewal treatments would be funded in the same way to continue to sustain the reduction in FSI resulting from initial provision. However, this is not guaranteed, and whatever funding source is employed a net increase in funding demand will result.

Source: Adapted from MUARC (2011b) and VicRoads (2010).

[10] Whereas this example is specifically concerned with cost implications, see Table 5.4 on the scope and effectiveness of a crash reduction program based on Safe System principles which draws on the same program and research study.

Perhaps the greatest issue is that of managing expectations, where adopting a Safe System approach is assumed to imply the widespread roll-out of primary and/or supporting treatments.

The funding challenge is further illustrated by the relative initial cost and differential maintenance and operating cost of a wider set of alternative treatments (Figure 5.2) to help mitigate the likelihood and consequences of rural run-off-road crashes. It is clear therefore that any additional treatments will have consequences for affordability in many circumstances and overall justification from an economic perspective, this being particularly so for lower volume rural roads where crashes are widely dispersed and may occur at locations with little or no crash history. This is typical of much of the secondary state road network, and local roads, and reinforces the need for speed management and alternative non-build solutions.

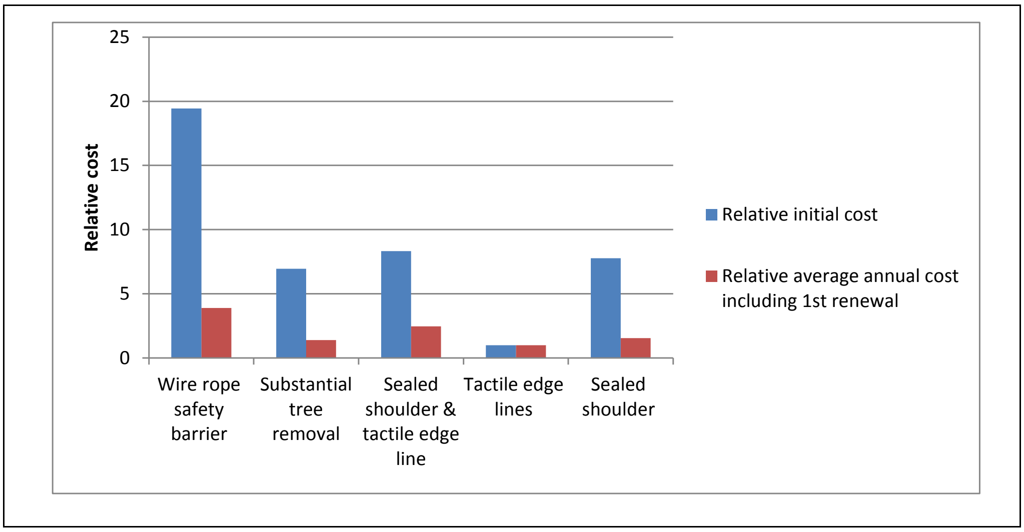


Figure 5.2: Relative costs of various treatments for run-off-road crashes

The issues raised above apply to any treatment program and therefore comprehensive analysis is vital to ensure long term objectives can be funded, and to ensure a maintenance legacy can be accommodated in the future. It is for this reason that a hierarchy of levels of service and associated physical infrastructure in conjunction with alternative management strategies is required.

5.4.4 Appropriate Processes, Systems and Tools

Various national, international and road agency specific processes and tools exist to undertake a gap analysis and develop business cases. They incorporate established road safety management, asset management and general road planning and evaluations processes to varying degrees, and increasingly offer the ability to assess FSI risks and estimate likely outcomes. It is through the application of such tools that treatment options are identified, evaluated and prioritised.

Purpose-built tools are available within a number of the road agencies for network level application and the evaluation of locations and proposals (Table 5.12), whereas more general planning (or cost benefit analysis) tools are more widely available. The road safety assessment tools are also supplemented by the iRAP family of tools, and will be further augmented or replaced by the ANRAM when it is available.

Table 5.12: Road agency road safety assessment and planning tools

Road agency crash assessment tools The national and international tools and the knowledge underpinning them are used widely by road agencies and have led to tailor-made tools which reflect local contexts and can be used to support business cases for proposed projects or programs and to calculate benefits. The NSW RMS Road Safety Impact Statement (RSIS) is an example and is applied for both state and national funding cases. Whilst it is intended for application to black spots, the user can nominate general crash rates and test the performance of alternative treatments. The process is incorporated in a spreadsheet tool and involves: ▪ Supplying data for a candidate site. ▪ Computing benefits and impacts, including the BCR and the cost-effectiveness (CE) of the treatment, i.e. the number of crashes (or FSI) saved per $. The RSIS recommends direct BCR methods are not applied other than where serious crashes occur, or are prevented, whereas the CE method is applicable in all cases and is also consistent with a Safe System. ▪ Application of a crash rates reduction matrix and a treatment life and cost matrix. Outputs include: ▪ strategic cost estimate ▪ candidate details. A further example is the VicRoads risk analysis and crash reduction factor (CRF) calculation tools (VicRoads 2010). These include a comprehensive set of treatments, and associated costs and CRF. They were used as a source for the case study of wire rope steel barrier (Table 5.11).
General investment planning tools This breed of tools includes the benefit cost analysis methods employed for project evaluation. They employ models such as the model road state-related crash rates (Table 5.6), but could be adapted to incorporate crash rates for particular treatments, e.g. where changes in speed limit, clear zone, barriers etc. are applied. Most are suited for BCR calculation, but with adaptation the outputs they produce could be employed for cost-effectiveness analysis.

The Safe System requires high standards in terms of the maintenance of safety-critical assets. Treatments should be chosen based on the highest crash risk and potential outcomes, with high traffic flow locations first, and then extending to cover the rest of the road system on a priority basis. However, those activities, for which deferment is not an option where public safety is the topmost priority, should be addressed first within defined response times.

Under the Safe System approach, whilst setting priorities solely on the basis of benefit-cost analysis criteria ratio may not be appropriate, subjecting alternative Safe System treatments to a life cycle cost minimisation analysis where the objective function is to maximise the reduction in FSI within the available budget is appropriate.

Conventional economic evaluation can also still be a valuable decision aid to compare the cost of reducing deaths and serious injuries by different treatments. It can provide evidence on the return on investment at a program level, both within and between programs, and should always be applied to non-safety specific major projects to estimate changes in FSI and crash cost savings.

Furthermore, as part of the prioritisation process, when an asset is deemed in need of replacement then a Safe System treatment should be considered as a first resort, particularly where the initial and future costs are comparable, e.g. frangible sign posts are comparable in cost to traditional posts and do not impose an increased maintenance or operating cost.

Phases 3 and 4: Take home messages for asset managers

- Comprehensive data is more widely available to identify performance gaps, e.g. in relation to the incidence and severity of crashes, and asset gaps. There is widespread adoption of crash risk assessment tools which can support other asset management needs.
- The knowledge of the performance of a wide suite of primary and supporting treatments makes evaluation possible, with this knowledge incorporated into operational tools.
- In many cases cost savings occur from using new or innovative solutions, with examples arising from better line markings and signs, and use of high friction aggregates.
- The issue of asset creep is significant, but is more likely to arise as a significant cost issue as a result of the need to fund the initial provision and to renew assets rather than as a substantial increase in maintenance and operating costs. Funding commitments, and models, to support the sustainable use and renewal of Safe System treatments are needed.
- Processes, systems and tools exist to identify risks and evaluate needs, and in many instances are keeping abreast of demand. The new ANRAM tool will be helpful in encouraging the integration of data analysis and program development. It could significantly increase efficiency by reducing the need for multiple systems across the different program areas provided it was developed further to integrate network level analysis. Considerations should, however, be given to the data demand and level of complexity to ensure the solutions are appropriate for all road agencies, including local government.
- An incremental approach to achieving a Safe System which addresses risks in a consistent and prioritised manner is preferred. Treatment selection depends on the road safety and asset preservation issues, and the level of risk to safety and asset preservation. Low cost treatments but high coverage, and value for money offer the potential for quick wins.

6 PROPOSED AMENDMENTS TO THE CURRENT AUSTROADS GUIDES

6.1 Guide to Asset Management

Whilst the focus of the Assets Guides (as stated in the GAM) is on the management of the physical road assets, the importance of total transport system management, which covers all activities concerned with the provision, operation, maintenance, renewal and disposal of transport infrastructure assets, is duly recognised. The GAM goes on to encourage road asset owners and managers to co-ordinate a range of activities, from transport planning, through design, implementation and operations in order to maximise community benefits.

It is therefore important that the Guide extends its current focus on physical assets from largely concentrating on pavement performance, to meet the promise of a broader perspective. Many aspects of a Safe System approach coincide with this objective, and therefore the following recommendations build on this link.

However, the level at which this should be done needs consideration, since any change will have significant implications for other series, as well as the individual parts of the GAM. For example, whereas the strategic perspective could be extended, as suggested above, the detail to which asset data collection, performance modelling and treatment selection is addressed should be carefully considered. A balance needs to be struck with a preference to give priority towards informing network level strategy and program development which maximises the benefits from the component parts. Greater integration of information supply and management is essential for this to happen.

Specific areas for improvement in the GAM are given below.

- *Part 1 Introduction to Asset Management.* The first need is to introduce Safe System principles into Part 1 as a valid and appropriate approach to maximise community benefits. This is entirely consistent with the philosophy of the Guide. An immediate recommendation is to include a Commentary on Safe System, and make changes in the main text. Other changes should include clear guidance on the use of brownfields standards, and associated planning horizons. This is because they can significantly affect infrastructure costs, both initial provision and life-cycle costs and ultimately their performance, and therefore the choice of solutions for different parts of the network over time.

- *Part 2 Stakeholder and Community Requirements.* Few changes are envisaged in the areas of the principles and methods of stakeholder engagement which account for a substantial part of the document. However, more examples could be provided particularly on seeking community input to priority outcome areas and examples which demonstrate how road agencies have responded, and plan to respond. This is highly relevant to making progress towards a Safe System, given the need for all stakeholders to contribute to reducing road trauma. The recent floods which have affected many parts of Australia and impact route availability objectives are a further example. Other examples, including the impacts of congestion on travel time and the preservation of road assets, should also be addressed to provide an appropriate balance of examples. They would also provide a more direct link with Part 3 which is intended to respond to stakeholder and community requirements. The examples should also encourage appropriate disaggregation to reflect the risks faced by different road user groups, and possible actions to address these.

- *Part 3 Asset Strategies* takes a strategic view of the network, considering both infrastructure management (including its preservation and development), and road use management. It is therefore appropriate to expand its scope to include a greater focus on road safety by incorporating a Safer Roads Strategy. This would encourage a more comprehensive whole of network approach to defining a road hierarchy and setting standards which means that any subsequent program development and gap analysis (in Part 4) considers the full suite of outcome areas which constitute the scope of the asset manager's stewardship of the network.
- *Part 4 Program Development and Implementation* gives practitioners guidance for decision making with respect to good practice asset management at a network level for program development and implementation. This includes identifying asset requirements, setting appropriate levels of service for maintenance intervention in developing a maintenance works program, the development of a total needs program and its evaluation, selection of maintenance treatment and capital works options and the process of prioritisation and optimisation of the programmed works to ensure best value for money. Program implementation covers developing appropriate delivery arrangements of the works program and includes public reporting and information dissemination about the program and the media used to achieve this. Accommodating Safe System requirements would facilitate the oft quoted need to break down silos, and would help maximise benefits starting at a point in the process where key decisions are made and can make a difference, and ensure network-wide programs and specific projects are coordinated.
- *Part 5 Asset Performance* covers both data acquisition and modelling. *Part 5A Inventory* is of particular importance and should be updated as a matter of priority to extend the guidance on inventory data collection, especially where the related information can be acquired using network level acquisition systems. This will ensure consistency with the data driven Safe System approach and the Australian National Risk Assessment Model (ANRAM), including the established knowledge base on crash performance. Completion of this will then feed into the decision support activities that are covered by Parts 3 and 4 above. The remaining sub-parts should remain largely unchanged.
- *Part 6 Bridge Performance* is concerned with how to best manage physical bridge assets. It provides guidance on the establishment and maintenance of bridge asset inventories, and on the monitoring of asset performance. It discusses the need for agencies to measure asset performance against objectives, and is primarily concerned with condition data collection and performance modelling at a network level. Because of its specialist nature and the need for manual inspections few changes are required with respect to a Safe System, although the design and specification of safety features will require consideration.
- *Part 7 Road-Related Assets Performance* addresses the management of the diverse and non-homogeneous groups of 'road-related' assets other than pavements and bridges. Although the strategic management of these assets is frequently overlooked in favour of a focus on the more conspicuous road and bridge asset groups, the successful performance of the road network as a whole is increasingly dependent upon the peripheral assets and systems which provide the environment for the road network and the support and operating systems for safe and efficient traffic management. The scope is therefore highly relevant to a Safe System. However, no significant changes are suggested with the exception that those assets which could be observed in a network level drive-over survey, e.g. as covered in Part 5A, should be added to the list of inventory items.
- *Part 8 Asset Valuation and Auditing* provides guidance on how to undertake asset valuation, to assist the asset manager with long-term management requirements, and how to implement an audit process to ensure work activities reflect the works program and satisfy the asset and organisational strategies (and in turn stakeholder requirements). It also describes approaches to presenting information to external stakeholders and other

customers by means of public reports and other media. No significant changes are suggested whilst it is recognised that the asset valuation and audit processes will need to account for the growth in assets required to support a Safe System.

6.2 Guide to Road Safety

The Guide to Road Safety (GRS) begins with a strategic perspective and moves on to more detailed site and project level assessments. Its nine parts comprise:

- *Part 1: Road Safety Overview*
- *Part 2: Road Safety Strategy and Evaluation*
- *Part 3: Speed Limits and Speed Management*
- *Part 4: Local Government and Community Road Safety*
- *Part 5: Road 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.*

The main need is to ensure the revisions to GAM are consistent with and draw on the understanding of road safety issues and solutions articulated in the GRS. Examples include the need for consistency in road hierarchy to ensure infrastructure related attributes of a Safe System are defined on an agreed basis, and are available for input to strategy and program development. A further example includes identifying strategies for different parts of the network, and the contributions to be made by different stakeholders and the community. Much of this has been shared in this Project.

6.3 Other Guides

Consistency is also needed within the following two Guides:

- *Road Design* with the main need to provide clear and consistent guidance on the use of brownfields standards, and planning horizons, and the relationship between standards and the road hierarchy. Greater reference to asset maintenance and life cycle costs is also required, and to the use of alternative solutions such as clear zones or barriers with this being important in the selection of solutions. Consideration of detailed design recommendations is required for different safety treatments where these affect performance and durability.

- *Project Evaluation* with the need for consistency in the treatment of issues such as crash costs, (where willingness to pay is now accepted nationally), and the definition of crash types, and option selection and prioritisation. It requires guidance on the appropriate use of benefit cost analysis, including the application of NPV, BCR and cost-effectiveness indicators, such as FSI saved per investment unit, as a means of selecting options and for ranking projects under budget constraint, taking account where appropriate of both capital and operating costs.

7 CONCLUSIONS

7.1 General

General conclusions which aim to support the incorporation of Safe System principles within an asset management framework are given below.

1. Significant opportunities exist for asset managers to better develop solutions through internal actions and in cooperation with other stakeholders and the community, to minimise harm in support of the Safe System objectives and principles which form the cornerstone of the Australian and New Zealand National Road Safety Strategies (NRSS).
2. The solutions which asset managers can employ and facilitate can extend beyond traditional asset maintenance and road safety practice, building on the Safe System philosophy recognising the need to manage crash forces to minimise fatal and serious injury (termed FSI) outcomes, and the range of infrastructure and road use management solutions which could help reduce road trauma.
3. Similarities between the Safe System and the Austroads Asset Management framework, and their underlying philosophies have been identified, and key process requirements have been defined, with a focus on the strategic asset management Phases 1 to 4. These were chosen because there are greater opportunities within these phases to maximise beneficial outcomes. They also provide greater opportunity for integrated solutions, and a practical framework for action.
4. The proposed integrated approach recognises core drivers, such as the NRSS, the need to manage parts of the network differently with a focus on risk management, incremental improvements and the opportunities afforded by new roads and major upgrades and the role of data and evidence based analysis in informing program development.
5. The forthcoming Australian National Risk Assessment Model (ANRAM) and New Zealand's KiwiRAP and other road agency guidelines and tools have the potential to make substantial contributions. The ANRAM investment decision framework also provides a useful classification to aid the selection of appropriate strategies for different parts of the network. The need is to do more, and build on established practices in the interests of maximising harm reduction. This will require a balanced approach considering all outcome areas as asset managers continue to operate within the broader asset management context to maintain and preserve existing assets, their decisions will be guided by Safe System principles and outcomes.
6. Knowledge gaps have been identified, including possible revisions to the *Guide to Asset Management* and other relevant Guides to aid the achievement of a Safe System.
7. Achieving the required progress is likely to require a strategic whole-of-business style approach harnessing and developing the capacity within different disciplines, and across different programs.

7.2 Specific Conclusions

Specific conclusions on issues identified for the project, addressed in relation to strategic asset management Phases 1 to 4, and relevant Austroads guidelines are given below.

7.2.1 Phase 1: Setting Policy Objectives

1. The existence of comprehensive and well communicated policies provides a clear basis for action covering all applications and requires asset management and safety objectives to be considered together from the outset.

2 Whereas asset managers may not set policy, it is clear that they have a significant role to play in contributing to, influencing and applying policy. Asset managers should seek to understand policy objectives and drivers and use them as a basis for strategy, program and project development and implementation. Opportunities exist to better inform policies based on performance evidence and whole-of-life-cycle costs.

3 With the emergence of the Safe System as a foundation for road safety strategies, it is considered reasonable to assume that a defence strategy against future claims should not alter drastically, whether the Safe System is brought into consideration during the proceedings or not.

7.2.2 Phase 2: Asset Strategies

1 International and regional (Australia and NZ) road agencies have identified key attributes for different roads, covering existing brownfield sites and greenfield sites, including new roads or major upgrades. These take account of road use and risk to help inform the development of asset strategies, and can be applied as part of the gap analysis process as input to program development.

2 Recent findings from the post-evaluation of Safe System treatments at a program level provide a sounder basis for informing strategy development, and program composition. They demonstrate significant economic benefits at a program level, and provide economic justification for adopting primary Safe System treatments particularly for more highly trafficked roads.

3 Speed management is being adopted as a measure in lower volume rural roads, in addition to its more widespread use in urban and sub-urban areas and offers a cost-effective alternative in many circumstances.

7.2.3 Phases 3 and 4: Tactical Planning and Programming, and Project Development

1 Comprehensive data is now more widely available to identify performance gaps, e.g. in relation to the incidence and severity of crashes, and asset gaps. Crash risk assessment tools are also more widely available to employ the data.

2 The knowledge base on the performance of a wide suite of primary and supporting treatments now makes more comprehensive evaluation possible, with this knowledge incorporated into operational tools.

3 In many cases cost savings occur from using new or innovative solutions, with specific examples arising from better line markings and signs, and use of high friction aggregates.

4 The issue of asset creep is significant, but is more likely to arise as a significant cost issue as a result of the need to fund the initial provision and to renew assets rather than as a substantial increase in maintenance and operating costs. Funding commitments, and models, to support the sustainable use of Safe System treatments are needed.

5 Processes, systems and tools exist to identify risks and evaluate needs, and in many instances are keeping abreast of demand. The new ANRAM tool is expected to be helpful in encouraging the integration of data analysis and program development. It could significantly increase efficiency by reducing the need for multiple systems across the different program areas provided it was developed further to integrate network level analysis. Considerations should, however, be given to the data demand and level of complexity to ensure the solutions are appropriate for all road agencies, including local government.

An incremental approach to achieving a Safe System which addresses risks in a consistent and prioritised manner appears to be the most suitable approach to managing safety risks whilst supporting other community needs.

7.2.4 Research and Development Needs

1 The review of relevant Austroads Guides concluded that:

- *GAM Part 1* could usefully be extended to include an additional Commentary on Safe System and appropriate text to help mainstream Safe System within asset management. Other areas of importance include the related aspects of road hierarchy and LOS, design concepts for brownfield and greenfield sites, use of benefit cost analysis and cost-effectiveness analysis in option selection and prioritisation, and appropriate planning horizons.
- *GAM Part 5A* could usefully be extended to include guidance on inventory collection on those Safe System related attributes which are appropriate to collect using network level data acquisition methods.
- Selected parts of the *Guide to Road Safety*, *Guide to Road Design* and *Guide to Project Evaluation* could be revised to ensure an integrated, consistent approach.

2 A gap in knowledge exists in the relationship between crash outcomes, including FSI, and asset condition. Areas of research will need to be identified particularly related to new asset types as the evidence base for estimating whole-of-life-cycle costs, including both maintenance and renewal components is very limited.

There exists significant potential to develop strategic level planning and reporting tools to help support integrated decisions on infrastructure and road use management across road agency outcome areas. These, however, need to be suited to the capacity of the different road agencies and relevant in terms of level of detail and cost to their intended use.

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APPENDIX A ANRAM DATA REQUIREMENTS

Table A 1: ANRAM/iRAP v3 Beta 3 input data requirements or each 100 m segment

Attribute
Jurisdiction*
Road stereotype*
Road name
Section
Distance (chainage at the start)
Length
Latitude
Longitude
Landmark
Comments
Carriageway
Upgrade cost
Vehicle flow (AADT)
Motorcycle %
Bicycle observed flow
Pedestrian observed flow across the road
Pedestrian observed flow along the road driver's side**
Pedestrian observed flow along the road passenger side
Land use – driver's side
Land use – passenger side
Area type
Speed limit
Speed limit – motorcycle
Speed limit – truck
Speed – 85th percentile
Speed – mean
Differential speed limits
Median type
Centreline rumble strips
Roadside severity – driver's side distance
Roadside severity – driver's side object
Roadside severity – passenger side distance
Roadside severity – passenger side object
Shoulder rumble strips
Paved shoulder – driver's side
Paved shoulder – passenger side
Intersection type

Attribute
Intersecting road volume
Intersection quality
Intersection channelisation
Property access points
Number of lanes
Lane width
Curvature
Quality of curve
Grade
Road condition
Skid resistance/grip
Delineation
Street lighting
Pedestrian crossing facilities – through road
Pedestrian crossing quality
Pedestrian fencing
Pedestrian crossing facilities – side road
Speed management/traffic calming
Parking (side friction)
Sidewalk – driver's side
Sidewalk – passenger side
Service road
Motorcycle facility
Bicycle facility
Roadworks
Image reference***
Sight distance
Road that cars can read***
Car Star Rating Policy Target***
Motorcycle Star Rating Policy Target***
Pedestrian Star Rating Policy Target***
Bicycle Star Rating Policy Target***
Observed FSI crash data (road section level only)*

* ANRAM only requirements.

** Driver's side – because of iRAP's international focus, data coding avoids using left/right-hand-side terminology. In Australia, 'driver's side' is always the right-hand-side of the carriageway and 'passenger side' is always the left-hand-side.

*** Optional.

Source: Personal communication ST1571 project team.

INFORMATION RETRIEVAL

Austroads, 2013, **Asset Management within a Safe System**, Sydney, A4, pp. 63. **AP-R442-13**

Keywords:

Asset management, safe system, road safety

Abstract:

This report documents the outcomes of an Austroads project which considered the asset management implications of the new Safe System approach and investigated what implementing a Safe System would mean for asset managers. The report provides a background to the Safe System and examines a range of infrastructure and road use management solutions which could help reduce road trauma. The solutions proposed extend beyond traditional solutions, building on the Safe System philosophy and integrating these with asset maintenance and road safety practice.