16th Road Safety on Four Continents Conference
Beijing, China 15-17 May 2013

IMPLEMENTING THE SAFE SYSTEM APPROACH TO ROAD SAFETY: SOME EXAMPLES OF INFRASTRUCTURE RELATED APPROACHES

Blair Turner
Australian Road Research Board (ARRB)
Vermont South, Australia
E-mail: blair.turner@arrb.com.au

ABSTRACT

The Safe System approach has been adopted by a number of global organisations as the best practice approach for delivering road safety. This approach marks a significant change in how road safety is implemented, and the outcomes sought. The Safe System approach has been adopted by a number of countries, including Australia as the guiding principle for achieving road safety outcomes.

This paper presents recent examples from Australia of how the Safe System approach may be implemented, particularly in regards to road infrastructure solutions. Details are provided on several initiatives, including the development of a Safe System framework to assess whether major projects are in accord with Safe System principles; work to embed Safe System objectives into the planning process; integration between asset management and safety; updates of the Australian and New Zealand guidance documents for road design to incorporate Safe System thinking; a process for speed limit setting to meet Safe System objectives; and research to improve the performance of road infrastructure to better achieve Safe System outcomes. Case studies are provided for several of these initiatives, and a discussion of future directions provided.

1 INTRODUCTION

There is an increasing recognition that traffic crashes are a major and growing cause of death in the world. More than 1.3 million people die in road crashes each year. This has led to the UN initiating the Decade of Action for Road Safety 2011-2020 to increase national and global action to save lives on the world's roads and to improve road safety action.

Australia has made good progress in reducing deaths and injury on the road in the last few decades but there is recognition that more needs to be done. The Safe System approach represents the latest evolution in road safety strategies in Australia. The approach was formally recognised at the Austroads Council Meeting of November 2003, and endorsed by the Australian Transport Council in 2004. It is now a key component of Australia’s national road safety strategy

This paper presents some examples of Safe System-inspired approaches from around Australia, but also highlights the need for a more concerted effort in this area.

2 THE SAFE SYSTEM

The Australian 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 made of human tolerances when designing road infrastructure (see e.g. Tingvall, 1998). The Sustainable Safety approach (Wegman and Aarts, 2006) is based on the following concepts, the first four of which relate specifically to road infrastructure:

- 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. 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.

In Australia, the Safe System approach is outlined in several Federal and state-based documents. The National Road Safety Strategy outlines the key Safe System principles as follows:

"a road safety approach which holds that people will continue to make mistakes and that roads, vehicles and speeds should be designed to reduce the risk of crashes and to protect people in the event of a crash".

Other key aspects of the approach are that:

- It is a holistic view, recognising the interactions among roads and roadsides, travel speeds, vehicles and road users
- It recognises that there are limits to the kinetic energy exchange which humans can tolerate (e.g. during the rapid deceleration associated with a crash) before serious injury or death occurs.
- given that humans as road users are fallible and will make mistakes there is a need for a transport system that is forgiving, and that death or serious injury should not occur in the event of a crash
- there is a requirement for a shared responsibility in addressing road safety.

In terms of road infrastructure, a key part of the Safe System approach is that the road environment be designed to take account of these errors and vulnerabilities so that road users are able to avoid serious injury or death on the road. Indeed, there is an obligation on those who manage the road network to provide a safe road and roadside environment. For almost all crashes there is likely to be some form of road improvement that could be made to reduce the likelihood and/or the severity of a crash.

3 DELIVERING SAFE SYSTEM INFRASTRUCTURE

Despite almost 10 years as the guiding principle for safety in Australia, there are still relatively few examples of Safe System-inspired approaches in Australia, including those relating to infrastructure improvements. There is a need for a more concerted effort in this area. The sections below provide some examples of projects that are based on the Safe System approach, particularly in relation to road infrastructure.

3.1 Safe System framework to assess major projects

There have been several attempts at the development of a framework to assess whether projects (either planned or existing) meet the objectives of the Safe System approach. Marsh (2012) developed a comprehensive approach that has now been used for several years in the state of Western Australia. In 2007, a Safe System Working Group was established to assist in achieving the aspirational target of zero deaths for a new highway in the first five years of its operation.

As part of the assessment, a ‘Towards Zero Framework’ was developed. This provided a structured approach to the assessment of the project against Safe System objectives. A key feature of this framework is that it seeks to limit forces in the event of a crash to those that can be withstood by the human body. The framework focuses on fatal and serious crash injury types with specific attention to run-off-road and head-on crashes (where speeds exceed 70 km/h); intersection crashes (where speeds exceed 50 km/h); and vulnerable road users (where speeds exceed 30 km/h).

Another key feature is the recognition that road authorities need to use their limited resources in the most cost-effective manner. To address this issue, the framework provides a ‘hierarchy of control’ for treatments. At the highest level, this involves treatments that prevent death or serious injury (e.g. forgiving road and roadside infrastructure including roadside barriers), while still considering competing demands such as community and road authority expectations (termed ‘sustainable solutions’). The second order treatments are those that provide real time risk reduction, including those that provide some form of pre-crash warning (e.g. ITS and audio-tactile road marking). The last level of the hierarchy involves general risk reduction, including other road and roadside treatments, enforcement and education.

Since its development the framework has been applied to a number of other projects, and there have been some interesting outcomes from this process. In some circumstances, traditional treatments have been replaced with others more in keeping with Safe System outcomes (e.g. greater use of wire rope barrier; replacing a proposed signalised intersection with a roundabout; introducing horizontal deflection on approach to pedestrian crossing points; use of Intelligent Transport Systems etc.). A further significant benefit identified from at least one project is that the process has the potential to reduce costs while improving safety outcomes. As an example, construction costs were significantly reduced for one project due to less extensive earthwork requirements. This stemmed from the use of barriers instead of a wide clear zone. This treatment also resulted in less environmental impact, as established vegetation was retained.

The state of South Australia has also developed a Safe System framework. The key objective of the framework is to ensure that projects deliver safety outcomes to minimise fatal and serious injury crashes, with the aspiration of reducing the chance of death and serious injury to as near to zero as possible. This tool was developed for use at various project stages (e.g. planning new roads; upgrades; assessment of existing infrastructure) and for different sized projects (large capital projects through to site specific assessments). Drawing from the experience in Western Australia (outlined above), a framework was developed and a trial undertaken.

The framework consists of a checklist that embeds Safe System principles. This is based on the interplay between the desired speed environment (based on road function), existing or predicted speed environment, and the infrastructure provided. Again, core to this understanding is the biomechanical tolerances of road users in different situations.

All system elements (road, vehicle, people, speed) need to work together to ensure this outcome as it is likely that no single element will produce near zero outcomes. It is also recognised that with current technology there is no absolute guarantee that the numbers of deaths and serious injuries will be reduced to zero. A Safe System approach uses the best available combination of existing solutions to reach as near to zero as possible.

A four-step process is used as follows:

1. consider the function of the road in light of Safe System principles
2. risk assessment undertaken using the Safe System framework
3. identify solutions/options
4. revise plans and operating strategies, and document decisions made.

The first step involves determining the intended function of the road based on the likely road users. Critical impact speeds similar to those of Marsh (2012) identified above were used (i.e. 30 km/h where vulnerable users are present; 50 km/h at intersections; 70 km/h where there is the potential for head-on crashes). These speeds provide an indication of the impact speeds that will ensure that when crashes occur they will not result in serious injury or death to vehicle occupants or other road users. If higher speeds than these are required, then certain measures are necessary to accommodate these speeds (typically infrastructure improvements that involve separation of road users, or protection from hazards).

Once this road function and the appropriate speed and infrastructure provision is determined, the Safe System Assessment Framework is applied (see Table 1).

Table 1: Safe System Assessment Framework

	Before Crash	During Crash	After Crash
Safer People			
Safer Speeds			
Safer Roads			
Safer Vehicles			

This framework considers the planning, design, construction, operation and maintenance issues as they relate to Safe System outcomes. It combines each of the Safe System 'pillars' (safer people, speeds, roads and vehicles) with the traditional Haddon matrix (Haddon 1980). This ensures that opportunities to reduce likelihood and severity before, during and after a crash are considered.

The framework has been populated with example questions that should be considered when assessing safety for any project (i.e. a checklist of issues). It ensures there is coverage of all key Safe System elements. As an example, in the 'before crash' category, the following examples are provided to ensure safer roads:

- Is infrastructure appropriate for speed environment based on Safe System levels?
- Is road layout predictable?
- Have all measures been taken to ensure motorists stay on the road?
- Is enforcement infrastructure provided?
- Is infrastructure provided to allow safe operation and maintenance of the network?
- Is the relative complexity of the design understood by drivers?
- Can incompatible vehicle types be separated?

Once all relevant issues have been identified, there is a requirement to document solutions that will mitigate these issues. The same framework structure is used to provide possible treatments to address the safety issues identified.

Based on the preceding steps, the initial plans / strategies will need to be revised to reflect these Safe System principles. This may need to be an iterative process, occurring several times until the project meets these requirements. The impacts of these changes need to be assessed to minimise negative consequences that may arise from these changes and that cost implications are captured. Where Safe System requirements cannot be met, reasons for this need to be documented.

This framework is expected to evolve over time with further application. Discussions are currently underway to determine how to embed this process within general practice including the possibility of including this within national guidelines on road safety audit.

For both the Western Australian and South Australian approaches, it is recognized that assessment is required at a very early stage of project development in order to affect the greatest benefit. For this to happen, the assessment needs to be embedded into the project development process.

3.2 Embedding Safe System objectives into the planning process

Embedding Safe System principles into the planning process as early as possible is likely to have considerable advantages in terms of safety outcomes. Often safety professionals have little input to a new design, particularly at the planning stage. This is typically the case for small projects or for situations where there is a perception that the new project will have a small impact on the surrounding area.

Both transport and land use planning authorities have a major influence on the way the road transport system functions and this influences the level of safety. Therefore, there is a need to ensure planning professionals receive guidance on how to embed Safe System principles into their proposals. Advice is also needed for planning professionals at state, territory and local government who undertake planning proposal assessments. Similarly, developers should also be encouraged to improve safety in the vicinity of any new development.

The project involves extensive stakeholder consultation, including input from various planning departments and practitioners on the most useful format for any guidance on this issue. It is seen as being of critical importance that the final project output is of a suitable format for quick take-up by planning authorities.

In parallel, reviews are currently underway to identify material of relevance to Safe System within the planning process, as well as of published land development planning material to identify how Safe System principles are currently applied.

This project is looking to provide guidance to help facilitate the inclusion of Safe System principles and solutions in the assessment of planning proposals, for use by planning and transport professionals.

3.3 The role of asset managers in delivering Safe System outcomes

Asset managers have historically had a role in helping to deliver safety objectives, but to date information on how asset managers can help deliver Safe System outcomes has not been available. In Australia, the two disciplines have often worked in isolation. A project was initiated to address these issues, and involved significant contributions from safety and asset management experts.

The Austroads Asset Management framework (Austroads 2009) was used as a platform to explore possible integration. Of particular importance are the strategic asset management phases where greater opportunities exist to maximise beneficial outcomes. The setting of policy objectives is particularly important, with a key requirement to make sure that asset management and safety objectives are considered together from the outset. Asset managers do not typically set policy, but it is clear that they have a significant role to play in contributing to, influencing and applying policy.

In terms of asset strategies, it was identified that there is a need to better recognise core drivers, such as 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. There is also an important need to understand the role of data and evidence based analysis in informing program development.

At the tactical and project development level there is now more comprehensive data 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 manage and help analyse the data. Knowledge regarding effective treatments available to asset managers has also improved and needs to be incorporated into operational tools.

Existing national guidance (particularly the Austroads Guide to Asset Management; Austroads 2009) need to be updated to better reflect the new Safe System principles. Such documents are used by asset managers, and provide an opportunity to inform and embed the new Safe System approach. As an example, it was identified that current guides could usefully be extended to include guidance on inventory collection on those Safe System related attributes. This is also likely to lead to increased efficiency and reduce costs by offering opportunities to combine surveys, say for asset preservation and safety management.

Achieving the required progress will require a strategic whole-of-business style approach harnessing the capacity within different disciplines, and across different programs.

3.4 Updates of Road Design Guides

As identified above, a key mechanism for improving road safety is to embed safety into the planning and design of new projects, or in the upgrade of existing infrastructure. The earlier within the process that this can be included, the better the likely outcomes.

One key way to influence road designers is to better embed Safe System principles in the design guidelines that are used by road agency staff and consultants. These documents are used on a daily basis, and typically form the basis of training for new designers.

A new project from Austroads has commenced this update process. This activity is linked directly to an action item from the new National Road Safety Strategy that states:

"Road authorities at all government levels will ensure that all new road projects apply Safe System principles".

The project commenced at the end of 2011, and has the intention of identifying areas within each part of the Guide to Road Design which may be revised to incorporate Safe System principles. There are 9 different parts to this guide, some with several sub-parts. These are as follow:

Part 1:	Introduction to Road Design
Part 2:	Design Considerations
Part 3:	Geometric Design
Part 4:	Intersections and Crossings - General
Part 4A:	Unsignalised and Signalised Intersections
Part 4B:	Roundabouts
Part 4C:	Interchanges
Part 5:	Drainage Design
Part 6:	Roadside Design, Safety and Barriers
Part 6A:	Pedestrian and Cyclist Paths
Part 6B:	Roadside Environment
Part 7:	Geotechnical Investigation and Design
Part 8:	Process and Documentation

These documents are available from Austroads (www.austroads.com.au) and are free to Austroads members (essentially all road agencies at Federal, state and local government level).

The approach taken to date in this project has been to:

- conduct a review of the current guide parts to identify current references to the Safe System approach
- review international literature to determine any design elements or principles that are not included in the guides but may be necessary to achieve Safe System outcomes
- review current projects in Australia and New Zealand to assess the degree of alignment with the Safe System principles
- draw upon international experience, including engagement with experts, to contribute to this review.

The intention is that any new design practice be included in guidance as each part undergoes review.

An early finding from this work is that there is a lack of guidance internationally that embeds Safe System principles into the design process. This includes the guidance documents that are available to those in countries that have embraced Safe System principles for a number of years.

It was also identified that the Safe System principles are consistent with the philosophies and content of the current design guides. Road designers have always had as a core consideration the provision of safer roads for all road users. A challenge has always been to provide safe infrastructure after taking into account all of the competing criteria. For example, the current guide for roundabouts (Part 4B) provides solid guidance on the construction of safe roundabouts. Perhaps of greatest use will be to provide designers with better information regarding the design options that they select. For example, it may be most useful to indicate the safest design options that may be available for any given situation. As an example, some form of decision tree could present the safest design option available to improve safety at an intersection (e.g. a roundabout). If a designer is unable to implement this design option due to constraints, the reason a lessor option is selected should be documented and mitigating measures used to minimize the safety risk from the use of that option.

The approach is currently being put to the test, with updates to Part 6 of the Guide to Road Design (on roadside safety) currently underway. This process will no doubt identify many issues, including some of the gaps in knowledge that remain in relation to road design and Safe System outcomes. Section 3.5 below provides information on a parallel project (to identify safety performance of some of our key infrastructure treatments) that may go some way to addressing such gaps.

3.5 Speed limit setting to meet Safe System objectives

The issue of appropriate speed limits required to achieve Safe System outcomes has received a lot of attention within Australia. This work stems from a better understanding of the biomechanical tolerances of humans in the event of a crash. Fildes et al. (2005) identified the typical speeds where death and serious injury can be minimized for different crash types (see above), while Cameron (2011) discussed optimal speed limits on various types of Australian roads within the Safe System context.

Jurewicz & Turner (2009) developed a process to help achieve implementation of these Safe System speed limits, with particular emphasis on the link between speed and infrastructure. The process identified involves the following four steps:

1. Identify what speed limit is expected for a given road class and function
2. What harm minimisation speed limit is applicable?
3. Carry out Safe System Analysis to match the speed limit with road infrastructure.
4. Manage driver perception of the road environment and traffic speeds if necessary.

The first of these steps is to determine the likely speed limit given the expected road class and function of the road. These are based on speeds typically used in Australia and New Zealand as indicated in Table 2. These speeds have evolved over many years, and typically do not reflect our more recent understanding of survivability for different crash types. The speeds from this assessment represent the high end of a possible speed limit.

Table 2: Typical speed limits in Australia based on road class and function.

Road class and function	Typical speed limit
Local roads with traffic calming Commercial streets with high pedestrian activity	40 km/h
Urban local and collector roads, Default urban speed limit	50 km/h
Urban undivided arterials with direct access Urban fringe / rural living local access roads	**60 km/h**
Urban undivided arterials with limited access Urban divided arterials with direct access	70 km/h
Urban divided arterials with controlled access Rural undivided roads of low design standard	80 km/h
Urban freeways Rural arterial and sub-arterial roads	100 km/h
Rural freeways Rural arterials of high design standard	110 km/h

The second step requires determination of the speeds that would be applicable under Safe System, taking account of road use and function. As indicated above, these are likely to be around 30 km/h where vulnerable road users are present; 40 km/h where there are unprotected roadside hazards; 50 km/h at intersections; and 70 km/h where there is no separation between opposing traffic streams.

The speed from such an assessment will likely form the lower end of a possible speed limit.

A significant gap may be evident from these first two steps (i.e. the Safe System assessment may suggest that a much lower speed is required than the assessment based on road class and function).

The third step involves an analysis to assess current or future road infrastructure that could be used to minimize the risk of key crash types. This may involve the provision of new infrastructure or a lower speed in order to meet Safe System objectives. Where it is not possible to eliminate all crashes, supporting road safety treatments should be used that will provide incremental improvements in safety.

The final stage of the assessment involves addressing the issue of driver perceptions. If driver speed is currently a lot higher than the desired speed, measures will need to be taken to help support the new speed limit. This might require additional features (e.g. narrower traffic lanes, gateway treatments) to lower the speeds, or alternatively a higher rate of enforcement.

This approach is now being further developed with the aim of producing model guidelines in the near future. Elements of the process have already been included in practice in some jurisdictions.

3.6 Performance of road infrastructure to better achieve Safe System outcomes

Earlier work on Safe System implementation in Australia identified a number of infrastructure treatments that were seen as being the most potentially useful in achieving Safe System outcomes (Turner et al. 2009). The list of treatments includes measures such as installation of roundabouts, greater use of wire rope barrier, and separation of vulnerable road users. However, such treatments do not always achieve the desired Safe System outcomes in terms of eliminating deaths and serious injury. In addition, the safety performance may vary for different road user types (e.g. pedestrians or motorcyclists).

As an example, research evidence suggests that roundabouts provide around 70% reduction in fatal and serious crash outcomes (e.g. BITRE 2012). This means that 30% of fatal and serious crash outcomes are expected to re-occur following treatment installation. There is a need to understand this ‘residual’ death and serious injury to help improve the design, selection, installation and management of such treatments. Such a process may also aid in the development of new infrastructure approaches.

This project will review the safety performance of a number of key road infrastructure treatments that have been identified as most useful in delivering Safe System outcomes. This assessment will be based on a targeted review of literature on the performance of road infrastructure, including input from international experts on this issue. It will also involve detailed analysis of crash data to determine fatal and serious crash causation. It is hoped that this information will lead to better design of such infrastructure, and ultimately a greater reduction in fatal and serious injury crashes.

4 CONCLUDING REMARKS

It is now almost a decade since the Safe System approach was formally adopted within Australia. Although the core concepts are well understood and accepted, the implementation of the approach has been slow. However, in recent years a number of projects have attempted to address the issue of implementation, particularly in relation to infrastructure. There are still many barriers to the adoption of Safe System infrastructure, cost not being least of these.

One common finding from work conducted to date is that to successfully embed Safe System in infrastructure delivery there is a need for this to occur at very early stages of program and project development. This in turn requires inclusion of Safe System thinking as an integral part of relevant policy and procedures. In order for this to happen, leadership at senior road agency level is required.

This project provides several examples of approaches that are being taken in Australia. This list is not exhaustive, and other infrastructure initiatives are also underway (e.g. guidance for those in local government). Through examples of good practice and exchange of information regarding this practice, both within Australia and internationally, it is hoped that further substantial improvements can be made in road safety. This issue of information exchange is of critical importance, and the key intention of this paper.

REFERENCES

Austroads 2009, Guide to asset management: part 1: introduction to asset management, AGAM01/09 Austroads, Sydney, NSW.

BITRE 2012, Evaluation of the National Blackspot Program: Volume 1, Bureau of Infrastructure, Transport and Regional Economics (BITRE Report 126, Canberra, Australia.

Cameron, M 2011, Rationalisation of speed limits within the Safe System approach, Australasian Road Safety Research, Policing and Education Conference, Perth, Australia.

Fildes, B Langford, J Szwed, N & Corben, B 2005, Discussion paper on the balance between harm reduction and mobility in setting speed limits. Unpublished report. Monash University Accident Research Centre.

Haddon, W 1980, Advances in the epidemiology of injuries as a basis for public policy, Public Health Reports, vol.95, no.5, pp 411-421.

Jurewicz, C & Turner, B 2009, Infrastructure/Speed Limit Relationship in Relation to Road Safety Outcomes. Austroads, Sydney, Australia.

Marsh, B 2012, Towards Zero Road Planning, Design and Construction, 25th ARRB Conference – Shaping the future: Linking policy, research and outcomes, Perth, Australia.

Theeuwes, J & Godthelp, H 1992, Self-explaining roads. Proceedings of the first world congress on safety of transportation. Delft, the Netherlands.

Tingvall, C 1998 The Swedish 'Vision Zero' and how parliamentary approval was obtained. Road Safety Research, Policing, Education Conference, 1998, Wellington, New Zealand.

Turner, B Tziotis, M, Cairney, P & Jurewicz, C 2009, Safe System Infrastructure National Roundtable. Report ARR 370. ARRB Group, Vermont South, Australia.

Wegman, F & Aarts, L (eds.) 2006, Advancing sustainable safety: National Road Safety Outlook for 2005-2020. SWOV Institute for Road Safety Research.