Guide to Road Safety Part 7: Road Network Crash Risk Assessment and Management

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Abstract
This report introduces the concepts of risk assessment and risk management in the road safety network context. The joint Australia and New Zealand Standard on risk management (AS/NZS 4360:2004) is used as the basis and structure for this document. The issues of communication and consultation, establishing the context, identifying risks, analysing risks, evaluating risks, treating risks, and monitoring and review are discussed. Examples of risk in the road safety context are provided, including those relating to road trauma, legal risk, and risk from adverse public opinion. Case studies are provided to assist practitioners in the assessment and management of risks on their networks.

Keywords
safety, risk, risk assessment, risk management

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Summary

This document describes the processes for assessing and managing different types of road safety risks on a road network. A range of issues are covered along with illustrative examples. However, the main focus is on risk assessment and management processes.

The joint Australian and New Zealand Standard on risk management (AS/NZS 4360:2004) is used as the basis and structure for the document. The stages of risk assessment and management as provided by the Standard are as follows:

Each stage of this process is discussed in the context of road network crash risk. Risks including those relating to legal risk and risks from adverse public opinion are discussed, although the main focus is on the risk relating to road safety trauma.

At each stage of the process, there should be communication and consultation with relevant internal and external stakeholders, including community groups, road user groups, police, elected representatives, asset managers, operation managers, health care professionals, relevant state and local government agencies, funders for road safety and local residents. It may be useful to develop a communication plan to help facilitate this process. Such communication is important to enable understanding of the decisions made, and also to identify the perceptions regarding risk by stakeholders.
Establishing the context is important to gain appreciation of all factors which might influence the ability to meet the intended outcomes. It involves establishing the external context, including identifying external stakeholders, relevant strategies, regulatory issues and the financial environment. It also involves establishing the internal context, including discussions with internal stakeholders, and reference to all relevant strategies and plans. Establishing the context includes defining the goals and objectives, and the scope or range of activities which the management process should cover. These include road trauma levels/crash types/crash costs, the legal context and liability, and public opinion. In addition, there is a need to develop some criteria against which the risk is to be evaluated. This includes assessing the needs for treatment based on financial, social, legal or other criteria.

Identifying risks involves the identification of risks to be managed, and a systematic approach is required to ensure that all relevant risks are identified for inclusion in later analysis. Various tools including the Haddon Matrix may be used in this identification task. Risks that are under the control of the organisation should be identified, as well as those that are not. Consultation with internal and external stakeholders is important in identifying all relevant risks.

An analysis of risks requires an understanding of the level of risk so that decisions can be made about how or whether to treat the risk. This involves assessing issues such as the consequences and likelihood of an event, including the magnitude of consequences should the event occur. Analysis of events can be quantitative (including analysis of historical data), semi-quantitative or qualitative (including expert judgement). Communication and consultation with relevant stakeholders is required as part of this process.

An evaluation of risks is required in order to select those risks that require treatment, and to prioritise them. Given a finite level of resources it is usually not possible to treat all potential risks. It is important to prioritise risks in order to produce the maximum benefit from the limited available resources. It is also important to communicate and consult with all relevant stakeholders during the prioritisation task. A number of tools are available to assist in the evaluation task, and the document discusses a number of these from Australia, New Zealand and the UK.

Once an assessment of the risks has been undertaken, and those risks that need to be treated have been identified, it is then necessary to assess available options for the treatment of those risks. A treatment plan should be produced including details of how the risks will be treated, who will be responsible, and what the expected outcomes are. Close communication and consultation with stakeholders is required when treating risk.

Ongoing monitoring and review is required throughout the risk management process. This is to ensure that progress is being made against the treatment plan, and that continual improvement can be made. As an example, it is important that the effectiveness of treatments is monitored so that this information can be included in future selection of appropriate treatments. It is also important to evaluate the influence of changing internal and external factors in this process.

Case studies are provided to illustrate examples of risk assessment and management in the road safety context.
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1. **Introduction**

1.1 **Background**

This Part of the Austroads Guide to Road Safety describes the processes for assessing and managing different types of road safety risks on a road network. A range of issues are covered in this document, along with illustrative examples. However, the main focus of this Part is on risk assessment and management processes. The joint Australian and New Zealand Standard on risk management (AS/NZS 4360:2004) is used as the basis for the document, and is recommended reading for those seeking further details on this issue.

Risk assessment at different management levels requires different tools. At a national or state level safety risks need to be determined globally, identifying broad trends and leading to national or state strategies. At the other end of the spectrum, at an operational level, site risks can be evaluated and managed in a significantly more detailed manner, including identification and management of specific features or hazards. This document is primarily aimed at the management of risk at the operational level.

The examples used mostly relate to road trauma, but some coverage is made of legal risk, and risk relating to adverse public opinion. When discussing road trauma, examples from road safety engineering are mainly used, but the principles apply to all types of safety interventions.

Risk management in the road safety context should be considered as part of a ‘Safe System’ approach (e.g. ATSB, 2004a). This suggests that:

*the prime task for transport designers, regulators and policy makers is to minimise the total risk in the system by:*

- determining the relevant risk factors in a given situation
- determining which factors can be effectively manipulated
- determining which countermeasures will produce the desired outcomes (p.17).

This section introduces the concepts of risk and risk management, the aims and benefits of risk management, and barriers to implementation. Section 2 discusses the risk management process, while Section 3 outlines the risk context with reference to road trauma, the legal context, and public opinion. Sections 4, 5 and 6 discuss the risk assessment process, while Section 7 provides details about the treatment of risk. Section 8 discusses the importance of monitoring and review in the risk management process, while the final section provides case studies of risk assessment and management in the road safety context.

1.2 **Definitions**

The terms ‘risk’ and ‘risk management’ are used fairly regularly in everyday English, and this makes the need to clarify what is meant by these terms in the context of this document more important. In general, risk management is often thought of as managing internal and external influences to maximise opportunities. In road authorities it could be seen as managing internal and external influences to maximise positive outcomes, including safety, legal liability, public opinion, and budgets. It could also include minimising the potential for damage (human, financial or image), loss, injury, or death.

Examples of risk in a road authority include the risk of:

- crashes on the road network
- public outcry
- road or bridge failure
• political influence
• unmarked services during construction (i.e. costs for relocation of services)
• legal action.

However, for the purpose of this document, the definitions used in the joint Australian and New Zealand Standard on risk management (AS/NZS 4360:2004) have been adopted, where risk is defined as:

*The chance of something happening that will have an impact upon objectives* (p.4).

In addition, the Standard states that risk often refers to an event, the likelihood of it occurring, and the consequences resulting from it should it occur.

The risk management process is defined as:

*the systematic application of management policies, procedures and practices to the tasks of communicating, establishing the context, identifying, analysing, evaluating, treating, monitoring and reviewing risk* (p.5).

### 1.3 Principles of risk assessment and risk management

AS/NZS 4360:2004 provides details as to the stages of risk assessment and risk management. The stages are:

• communicate and consult
• establish the context
• identify risks
• analyse risks
• evaluate risks
• treat risks
• monitor and review.

Each of these stages is explained in Section 3, and examples are provided in the latter sections of this document.

### 1.4 Aims and benefits of risk management

AS/NZS 4360:2004 highlights 10 benefits of risk management. All of these issues are relevant to some degree in the road safety context. These are:

• fewer surprises (including mitigating the effect of adverse events through forward planning)
• exploitation of opportunities (with a better understanding of risks, there is a greater confidence to seek opportunity)
• improved planning, performance and effectiveness
• economy and efficiency (especially important in the road safety environment where there are limited resources)
• improved stakeholder relationships (through identification of stakeholders and dialogue)
• improved information for decision making
• enhanced reputation
• director protection
• accountability, assurance and governance
• personal wellbeing.

1.5 Perception of risk

There are often differences in the perceived level of risk, and the actual risk level. This difference is pronounced when comparing public perception of risk with actual risk, because the public and media perception of risk is often focused on isolated, high profile events. One child killed on the way to school, a school bus crash, a hazardous goods vehicle or a large truck or road train invokes the outrage response with full media coverage and calls for immediate action. However, lower profile events that are far more numerous often receive little attention, despite the greater impact on overall trauma.

Individual perceptions of risk are also likely to differ, indicating a need for wide consultation when managing risk.

1.6 Barriers to the introduction of risk management

Risk management is an important part of the overall management process, and needs to be embedded in this process to have greatest effect. However, there are sometimes barriers to the successful implementation of risk management. Medbury (1995) suggests that these include:

• problems selecting who will drive the program (role conflict)
• financial and staff restraints
• no previous ‘loss’, so therefore no need for risk management
• complacency or resignation to the status quo
• risk management seen as a low priority issue
• cultural barriers to change.

Medbury indicates that most of these barriers relate to management, and therefore strong and genuine commitment is required to the risk management philosophy and methodology. Following from this, commitment is required from all relevant staff, and this can be achieved through effective education and communication.
2. Principles of Risk Assessment and Risk Management

2.1 Introduction

This section introduces the principles of risk assessment and management in the road safety context. The aims and benefits of risk assessment and risk management are discussed, including those in relation to the internal context (for example budgets, policy, internal stakeholders and capabilities) and external context (including external policy and public opinion) for risk management.

2.2 The risk management process

AS/NZS 4360:2004 is highly relevant to the road safety setting. The risk management process from that Standard is presented below:

Figure 2:1: Risk management process overview

Source: AS/NZS 4360: 2004
There are seven key elements to the risk management process, discussed in brief below. Full details can be found in the joint standard, and the companion guide to this (HB 436:2004). The tasks of identifying, analysing and evaluating risks are often referred to as risk assessment, while the whole process is considered as risk management.

2.2.1 Communicate and consult

At each stage of the process, there should be communication and consultation with relevant internal and external stakeholders. This should also occur for the process as a whole. It may be useful to develop a communication plan to help facilitate this process. Such communication is important to enable understanding of the decisions made, but also to identify the perceptions regarding risk by stakeholders.

Stakeholders will vary according to local circumstances, but should include:
- community groups
- road user groups
- police
- elected representatives
- automobile associations
- asset managers
- operation managers
- health care professionals
- relevant state and local government agencies
- funders for road safety
- local residents.

2.2.2 Establish the context

This step is important to gain appreciation of all factors which might influence the ability to meet the intended outcomes. It involves establishing the external context, including identifying external stakeholders, relevant strategies, regulatory issues and the financial environment. It also involves establishing the internal context, including discussions with internal stakeholders, and reference to all relevant strategies and plans.

Establishing the context includes defining the goals and objectives, and the scope or range of activities which the management process should cover. These include (but are not limited to):
- road trauma levels/crash types/crash costs
- the legal context, and liability
- public opinion.

In addition, there is a need to develop some criteria against which the risk is to be evaluated. This includes assessing the needs for treatment based on financial, social, legal or other criteria.

Finally, it is suggested that the structure for the rest of the process be defined, including sub-dividing activities into a set of steps which provide a framework to assist with delivery and to ensure that risks are not overlooked.
2.2.3 Identify risks

This step involves the identification of risks to be managed, and a systematic approach is required to ensure that all relevant risks are identified for inclusion in later analysis. Risks that are under the control of the organisation should be identified, as well as those that are not. Consultation with internal and external stakeholders is important in identifying all relevant risks. Information on techniques that can be applied in the identification of risks is highlighted in Section 4.

2.2.4 Analyse risks

An analysis of risks requires an understanding of the level of risk so that decisions can be made about how or whether to treat the risk. This involves assessing issues such as the consequences and likelihood of an event, including the magnitude of consequences should the event occur. Analysis of events can be quantitative (including analysis of historical data), semi-quantitative or qualitative (including expert judgement). Communication and consultation with relevant stakeholders is required as part of this process. Further details on types of analysis including examples from the road safety context are provided in Section 5.

2.2.5 Evaluate risks

An evaluation of risks is required in order to select those risks that require treatment, and to prioritise these. Organisations are unable to treat all potential risks, given a finite level of resources, and this is also true in the road safety context. It is important to prioritise risks in order to produce the maximum benefit from the limited available resources. It is also important to communicate and consult with all relevant stakeholders during the prioritisation task. The issue of risk evaluation is dealt with in detail in Section 6.

2.2.6 Treat risks

Once an assessment of the risks has been undertaken, and those risks that need to be treated have been identified, it is then necessary to assess available options for the treatment of those risks. A treatment plan should be produced including details of how the risks will be treated, who will be responsible, and what are the expected outcomes. Close communication and consultation with stakeholders is required when treating risk. Details for this stage of the process are provided in Section 7.

2.2.7 Monitor and review

Ongoing monitoring and review is required throughout the risk management process. This is to ensure that progress is being made against the treatment plan, and that continual improvement can be made. As an example, it is important that the effectiveness of treatments is monitored so that this information can be included in future treatment plans. It is also important to evaluate the influence of changing internal and external factors in this process. The issues surrounding monitoring and review in the road safety context are presented in Section 8.
3. Establishing the Context

An appreciation is required of all factors that might influence the ability to meet the intended outcomes. To gain such an appreciation, there is need for the following:

- communication with internal and external stakeholders
- review of relevant internal and external strategies
- review of regulatory issues
- appreciation of the financial environment and funders, both internal and external
- definition of the goals and objectives.

Also important is an understanding of the safe system framework (see Section 1.1). This considers the system (vehicles, roads, road users and their physical, social and economic environments) as a whole, including the interaction between the individual elements.

In the road safety context there are a number of risk types that can impact on authorities. Most familiar are those relating to the level of road trauma, including number of crashes, crash types and crash costs. However, there are other risks that need to be considered when setting the context, and when identifying issues that might impact on outcomes. The legal context is an increasingly important risk that needs to be managed by authorities, and public opinion should also be included in the risk management process. Each of these issues are discussed below, and used as the basis for discussion throughout the rest of this document.

3.1 Road trauma

Road authorities in Australia currently manage a road system on which around 1800 people are killed, and approximately 22,000 people seriously injured every year (average since 1990, ATSB, 2004b). In New Zealand the figure is around 450 deaths a year, with 12,500 injuries (average per year between 1999 and 2003). Effective management of the road network is a key performance indicator for all road authorities, and as the key provider of road infrastructure there is an obligation to provide a safe road environment and to minimise this risk.

Road trauma, and the social and economic costs associated with it is an area of risk that needs to be managed by authorities. Authorities are in a leading position to reduce trauma levels on their roads through a variety of means, but particularly through road engineering. Examples are provided in later sections of this report on managing risks relating to road trauma.

3.2 Legal context

There is more than a moral obligation on road authorities to provide a safe road environment, with legal obligation (particularly in Australia) also an issue. Given the differing legal situations in Australia and New Zealand, responsibilities for each are treated separately.

3.2.1 Australia

It is difficult to provide generic advice in this section given the differences across jurisdictions, and the fluid nature of the legal situation. Legal advice should be sought at the local level.
Traditionally, the non-feasance rule has provided authorities with immunity from liability for their failure to repair and maintain the roads in their jurisdiction. However, recent test cases (most notably *Brodie v Singleton Shire Council*) have changed this situation with the limitation of non-feasance immunity. This has implications for Australian authorities and may leave authorities open to legal liability when crashes occur. The non-feasance immunity has been replaced by a recognition that road authorities owe all road users a duty of care, and must do what is reasonable to be aware of deficiencies in the road system, to assess and prioritise them, and have a system for remediying them (*Sarre 2003*). This responsibility covers the full road reserve, and by implication, all road users (including pedestrians).

Road authorities are obliged to have in place reasonable programs of inspection to allow them to identify problems with their roads. This assessment should take into account the fact that road users might fail to take proper care of their own safety. The road authority should have in place arrangements to make sure that deficits which pose a risk to road users are dealt with in a reasonable time, having regard to available resources.

It should be noted that the requirement of duty of care does not demand that there be no deficiencies in the road system – only that a road authority will do what is reasonable to monitor and remediye problems. The court decisions recognise that the resources available to an authority, including the availability of material and skilled labour, may limit how quickly repairs can be made, and how work is to be prioritised. If this results in a delay to remediying a situation which is hazardous for road users, the road authority should consider other alternatives such as using signs to alert road users of the hazard or, in extreme cases, closing the road.

Different jurisdictions have responded to the recent test cases in different ways, with some jurisdictions reintroducing legislation (for instance in Queensland sections 35-37 of the *Civil Liability Act 2003* provide limited protection of a nature similar to non-feasance, although there are specified exceptions to its application within the Act itself so it is not a complete protection), and many have taken a more active role in managing risks. It is beyond the scope of this document to address the legal situation in each jurisdiction, and authorities are advised to seek local legal advice when addressing the legal context.

### 3.2.2 New Zealand

In New Zealand, road controlling authorities have no specific duty under law to consider and implement measures to address road safety risk. Instead, personal injury is considered a community responsibility and individuals who are injured are not entitled to sue whether the injury was caused by individuals or organisations.

A consultative exercise was undertaken during the development of the *NZ Road Safety to 2010 Strategy*, and this indicated agreement on the need for a systematic approach to road safety engineering management. Road controlling authorities (RCAs) supported such an approach through Safety Management Systems, or SMS (see, for example, Greenwood & Denton, 2003; Greenwood, 2004; Land Transport New Zealand, 2006). In defining SMS, Greenwood (2004) suggests that they consist of four major components:

- the strategic road safety direction of the RCA including the vision and plans to achieve it. The RCA partnerships needed to deliver safer roads are also identified
- the road safety ‘toolbox’ of delivery including crash reduction studies, safety audits, data collection, adopted standards and guidelines. These generally relate to the RCA’s road hierarchy, staff structure, roles and technical expertise requirements
- the management control systems and responsibilities for the SMS including road safety engineering processes that will be used
- continuous improvement/audit regimes to ensure best practices are in place and are being followed and delivered for the road users.
Initially it was thought that the development and use of SMS by RCAs would be made a requirement through legislation, although this idea was later dropped. Instead, strong support is provided by Land Transport NZ in the development of authority-based SMS. These have now been introduced in most NZ authorities as a means of achieving safety targets, and have implications in the assessment and management of risk.

Transit NZ has recently produced its strategic plan (Transit NZ, 2004), and other RCAs have a road safety strategy within their SMS. Most NZ RCAs therefore have a statutory objective specifically identifying road safety delivery rather than a clear legal obligation.

### 3.3 Public opinion

When considering the context, community needs and expectations need to be carefully considered. Communities are increasingly demanding safety on their road networks, and there has been increasing media interest in road safety issues. As discussed, there are differing perceptions as to levels of risk. A car hitting a train will often make front page news, whereas a single vehicle run-off-road crash will hardly rate a mention. The latter event is the far more common, and so carries a greater degree of risk in terms of overall trauma.

Alternatively, individual road users often perceive the risk associated with individual journeys as being relatively minor. Therefore, it is often difficult to persuade individuals to change their behaviour in order to reduce risk. However, when aggregated, changes in behaviour can have a high cumulative effect on overall safety. Rumar (2002) suggests that the crash risk in every trip is microscopic, but that an individual may make many such trips over time, and that the sum of all of these risks is substantial over a longer period. Even greater is the collective risk over the whole community.

Levels of perception may not be based on the actual level of risk, and this is an issue that needs to be managed. Cherry and Fishburn (1996) suggests that as an individual:

> You do NOT represent the average road user. Always resist making judgements based on a sample of one (you)!

It is important to avoid making judgements of acceptable risk from an individual point of view, and so consultation with key stakeholders is required when defining objectives.
4. Identifying Risks

4.1 Introduction

Once the context has been established, and goals and objectives have been set, the first step of the risk assessment involves the identification of risks to be managed. Consultation with internal and external stakeholders is important in this process, and this identification should be done in a systematic way. The examples of road trauma, legal and public opinion have been used as types of risks. These are the risks of most relevance in the road safety environment, but there are others that may be of importance, and it is up to the authority to identify all risks that may be of relevance.

4.2 Road trauma

There is a large variety of factors that contribute to road crashes. In identifying risks at the network level there is a need to take a systematic approach to ensure inclusion of all of these relevant risks. Ogden (1996) summarised the factors determined as contributors to road crashes in the UK and the US (see Figure 4.1). In reviewing the data Ogden highlighted that regardless of the contributing factor there is often an engineering solution to the problem that would eliminate or reduce the severity of a crash. To determine this solution an understanding of the human and vehicle factors should be considered.

Figure 4:1: Factors contributing to road crashes as a percentage

<table>
<thead>
<tr>
<th>Contribution</th>
<th>UK study</th>
<th>US study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road environment only</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Road user only</td>
<td>65</td>
<td>57</td>
</tr>
<tr>
<td>Vehicle only</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Road and road user</td>
<td>24</td>
<td>27</td>
</tr>
<tr>
<td>Road user and vehicle</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Road and vehicle</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Road, road user and vehicle</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

In the early 1980s Haddon developed a useful conceptual framework for considering the factors which contributed to road crashes. It consisted of a matrix of potential risks involving the human, vehicle and road, and how these can influence safety before, during and after a crash (see Figure 4.2 for an example Haddon Matrix). The matrix can be used as a way of developing a comprehensive set of possible crash countermeasures.

Figure 4:2: Haddon Matrix showing possible crash countermeasures

<table>
<thead>
<tr>
<th>Element</th>
<th>Before a crash</th>
<th>During a crash</th>
<th>After a crash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>Training, education, behaviour (e.g. not drinking), attitudes, conspicuous clothing on pedestrians and cyclists</td>
<td>Wearing in-vehicle restraints</td>
<td>Prompt emergency medical service response</td>
</tr>
<tr>
<td>Vehicle</td>
<td>Primary safety (e.g. good brakes, roadworthiness, visibility)</td>
<td>Secondary safety (e.g. occupant protection)</td>
<td>Devices to attract attention (e.g. mobile phone, horn)</td>
</tr>
<tr>
<td>Road</td>
<td>Delineation, good road geometry, good surface condition, visibility</td>
<td>Roadside safety (e.g. frangible poles), adequate crash barriers</td>
<td>Emergency median breaks and shoulders provided on freeways</td>
</tr>
</tbody>
</table>

Source: Austroads, 2004
The insights provided by the Haddon Matrix have contributed to the present Safe System approach promoted in the Australian National Road Safety Action Plan for 2005/6 (Australian Transport Council, 2004) and used as a framework for this series of Guides. The goal of this approach is to provide safe travel for all road users by minimising the risk posed by the different interacting elements of the road transport system. Therefore, when considering the potential for crashes (as well as treatments), it is important to recognise the interacting elements that contribute to road crashes. Within the Safe System framework, the three essential aspects of the road transport system with which road users interact are:

- safer speeds – speed limits which are appropriate for the function and construction of the road, terrain, and adjoining land use
- safer vehicles – vehicles which protect occupants through structural design, protective equipment and features designed to ensure use of protective equipment (e.g. seat belt reminders), with design features which reduce injuries to vulnerable road users, and which provide better conspicuity of the vehicle and signals (e.g. through high-mounted brake lights or daytime running lights)
- safer roads and roadsides – treating sites with adverse crash histories or which have the potential to generate higher than average numbers of crashes, roll-out of cost-effective road improvements and mass action programs, providing safer roadsides.

A number of the causes of road crashes are outside the influence of road authorities (especially at local level). However, it is useful to identify all risks to determine which of these can be addressed through the risk management process. Those risks relating to the road will be of greatest relevance to authorities, while those relating to the vehicle will be least susceptible to change (at state and local level). For this reason, examples used in this document relate mainly to road safety engineering measures, although the methods discussed could easily be applied to other areas of treatment.

Appendix A outlines some of the issues associated with risk assessment and management and road user issues, and concludes that a risk management approach should be applied to the ‘human element’. However, such an application has not been conducted in any consistent way in the past, and this is an issue that needs to be addressed.

4.3 Legal risk

Identification of legal risks will need to be based on discussions with legal advisors within each jurisdiction. The legal situation varies between jurisdictions, and it is beyond the scope of this document to address this issue in detail. However, identification of risks might include the following:

- review of the legislative position in the local jurisdiction
- review of relevant precedents and test cases
- assessment of insurances, including the appropriate level of liability
- review of systems, including network management and project level tools.

4.4 Risk from adverse public opinion

In order to identify risks associated with public opinion in a systematic way, a community attitude survey can be undertaken. A representative sample should be selected, and a structured survey undertaken to gauge opinions on a range of safety issues. This can be repeated over time to assess changes in attitudes and opinions to key issues.

Given the influence of the media, and the degree of interest from the media in road safety related issues, media monitoring will also provide information from which potential risks can be identified.
5. Analysing Risks

5.1 Introduction

Following the identification of risks, the next stage in the risk management process is analysis of these to help determine whether to treat the risk, and if so, how. Consideration should be made as to the causes of the risk, and the likelihood and consequences that the risk will occur. Similar risks can be combined for ease of assessment, and low impact risks excluded from further analysis. This screening process is often necessary, as given limited resources, it is usually not possible to thoroughly assess and evaluate all risks. In some circumstances, a qualitative approach (this could be defined as any method which uses descriptors rather than numerical values when classifying risks) can be used as an initial screening, and will help identify where the level of risk does not justify a more in-depth quantitative analysis. Alternatively, a more in-depth quantitative investigation may be necessary to provide appropriate details. In addition, adequate data may not be available to undertake a quantitative analysis, and so a qualitative approach will be required.

This section highlights a number of issues relating to data and processes for risk analysis.

5.2 Sources of data

Once all sources of risk have been identified, there is a need to collect information on each of these to determine the level of risk. There are a number of sources of information that can be used, although in some cases it will be difficult (if not impossible) to collect relevant information with which to make informed decisions. Sources of information include:

- crash databases
- hospital or insurance data
- pro-active assessments of safety, including road safety audit findings, and network level assessments
- information from asset management and road maintenance
- road inventory data
- traffic volume, speed and vehicle classification data
- enforcement data
- monitoring data
- legal precedents
- public opinion surveys
- media monitoring.

A brief discussion on some of the key sources of data can be found in Appendix B.

5.3 Quantitative approaches

When assessing the risks for road trauma, blackspot analysis is typically used to identify locations with high levels of risk. Blackspot sites, lengths of road or areas with crashes over a minimum number per year are selected for inclusion in the analysis (for instance, three casualty crashes over a five-year period may be used as a minimum for a site). A list of sites is produced which forms a ‘short-list’ for more in-depth assessment and consideration for treatment.
However, a simple analysis of crash numbers gives no indication of the severity of the crashes involved, so often the crash or social cost is used (higher severities have a higher crash cost, and these costs can be aggregated by site, area or topic of interest). For example, this approach is used by Land Transport NZ (formerly the Land Transport Safety Authority) in the production of its blackspot listings for authorities (see Figure 5.1).

**Figure 5.1: Example of sites by social cost**

![Transport Safety](https://example.com/transport-safety.png)

**Auckland Region Road Safety Report 1999 - 2003**

<table>
<thead>
<tr>
<th>CRASH ROAD</th>
<th>SIDE ROAD</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>TOTAL</th>
<th>Dark Crash %</th>
<th>Wet Crash %</th>
<th>Crash Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>local roads</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FANSHawe ST</td>
<td>BEAUMONT ST</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>20</td>
<td>15</td>
<td>30</td>
<td>$6,150,517</td>
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<tr>
<td>NEW NORTH ROAD</td>
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<td>5</td>
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<td>2</td>
<td>1</td>
<td>5</td>
<td>15</td>
<td>7</td>
<td>13</td>
<td>$3,988,189</td>
</tr>
<tr>
<td>KARANGAHAPE ROAD</td>
<td>UPPER QUEEN ST</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>21</td>
<td>24</td>
<td>57</td>
<td>$3,669,117</td>
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<tr>
<td>TI RAKAU DRIVE</td>
<td>TE IRIKANGI DRIVE</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>12</td>
<td>33</td>
<td>42</td>
<td>$3,661,313</td>
</tr>
<tr>
<td>ALBERT ST</td>
<td>WELLESLEY ST WES</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>18</td>
<td>33</td>
<td>50</td>
<td>$3,522,929</td>
</tr>
<tr>
<td>SYMONDS ST</td>
<td>WELLESLEY ST EAST</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>13</td>
<td>38</td>
<td>31</td>
<td>$3,245,947</td>
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<tr>
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<td>GLENDALE ROAD</td>
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<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>33</td>
<td>11</td>
<td>$3,024,362</td>
</tr>
<tr>
<td>MAYORAL DRIVE</td>
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<td>4</td>
<td>4</td>
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<tr>
<td>VICTORIA ST WEST</td>
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<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>12</td>
<td>17</td>
<td>67</td>
<td>$2,559,102</td>
</tr>
<tr>
<td>MOUNT ALBERT ROAD</td>
<td>SANDRINGHAM ROAD</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>11</td>
<td>27</td>
<td>18</td>
<td>$2,503,706</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PONSONBY ROAD</td>
<td>HOPETOUN ST</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>50</td>
<td>10</td>
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<td>MOUNT EDEN ROAD</td>
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<td>1</td>
<td>1</td>
<td>9</td>
<td>11</td>
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<td>$2,392,913</td>
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<tr>
<td>CUSTOMS ST WEST</td>
<td>LOWER ALBERT ST</td>
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<td>4</td>
<td>5</td>
<td>4</td>
<td>15</td>
<td>40</td>
<td>73</td>
<td>$2,093,842</td>
<td></td>
</tr>
<tr>
<td>PORTAGE ROAD</td>
<td>SALEYARDS ROAD</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>15</td>
<td>33</td>
<td>20</td>
<td>$2,093,842</td>
</tr>
<tr>
<td>GREAT NORTH ROAD</td>
<td>TITIRANGI ROAD</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>12</td>
<td>33</td>
<td>8</td>
<td>$1,927,653</td>
<td></td>
</tr>
<tr>
<td>ONEWA ROAD</td>
<td>SYLVAN AVENUE</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>7</td>
<td>12</td>
<td>42</td>
<td>17</td>
<td>$1,927,653</td>
<td></td>
</tr>
</tbody>
</table>


In addition, crash risk analysis can be undertaken by including a measure of vehicle volume to crash information. This provides a level of crash risk by vehicle volume (for instance, crashes per million vehicle kilometres travelled or vkt) to identify routes, areas or crash types that fall above the average expected. Similarly, pattern analysis can be undertaken to identify common crash types for treatment (for instance drink drive, speed, fatigue, and run-off-road crashes). Crash costs can also be included in this type of analysis to indicate severity (for instance cents per vehicle kilometre, or dollars per kilometre of road. See LTSA, 1996).

It may be useful to determine risk by making comparisons with other similar groups or regions. This can also help identify issues to target for remedial action. Such comparisons are used internationally (e.g. ATSB, 2004c) to compare key performance figures (primarily deaths per population, deaths per registered vehicle, and deaths per vehicle kilometre travelled) for different jurisdictions. They are also used nationally, for example in New Zealand in the production of annual road safety reports, which highlight the safety of each authority. As an example, major cities form 'Comparison Group A', and each of these cities is compared to the all-group average. Comparisons made with similar authorities will have more relevance than data from the whole country. Differences between comparison groups can often be explained (e.g. high volumes of through traffic from outside the area will distort measures based on population), although in many cases these differences may help highlight issues that require attention.

In Western Australia, crash risk (defined as crashes per vehicle kilometre) patterns have been developed using five years of crash data. The network average crash risks identified can be used as benchmarks, allowing locations with higher than average risk to be targeted for improvement.
Further percentage rates are calculated to consider factors such as road type (sealed/unsealed, divided/undivided etc), night time crashes (which relates to delineation), fatigue and speed (for further details see Kidd & Willett, 2001).

Western Australia also produces road safety performance charts and maps across the network including road user type and crash type clustering. An internet based system called ‘Intersection Crash Ranking’ allows interactive reports to be produced for a single intersection, or a series of intersections by local government, region or state-wide, based on 5 years of crash data. Results can be ranked by crash frequency or crash cost (similar to Figure 5.1 above) and detailed summary reports produced showing crash types and road users.

Further examples of network level approaches are provided in Section 9.

Simulation or modelling techniques can also be applied where information allows, and this technique is a powerful tool in assessing network risk. These types of models assume knowledge of risk based on past experience and research. In considering the modelling of road safety indicators, Bergel (1998) produced a model to consider adjustments to be made to (monthly) crash data to enable comparison and evaluation of road safety initiatives. An example of the model is provided in Figure 5.2 below.

**Figure 5.2: Bergel model of road safety indicators**

<table>
<thead>
<tr>
<th>Levels</th>
<th>Risk exposure</th>
<th>Risk</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modelled variables</td>
<td>Traffic</td>
<td>Number of crashes (non fatal, fatal)</td>
<td>Number of victims (deaths, seriously injured, lightly injured).</td>
</tr>
</tbody>
</table>
| Explanatory variables | • Economic growth  
• Network length  
• Fuel price  
• Weather conditions | • Traffic  
• Economic growth  
• Network length  
• Fuel price  
• Weather conditions  
• Speed  
• Seat belt use | • Traffic  
• Number of crashes  
• Economic growth  
• Fuel price  
• Weather conditions  
• Speed  
• Seat belt use |

Consideration of this modelling provides an indication of the variables that are likely to influence the exposure, probability and severity of crashes on the road network.

### 5.4 Qualitative and semi-qualitative analysis

In some situations, there may be a lack of objective data with which to make a quantitative assessment of risk. For example, in assessing the level of risk based on legal liability, there is little objective information on which to base any analysis. In these cases, more qualitative approaches may be used. There are various models of qualitative risk assessment that are of relevance to road safety. These include:

- risk classification
- fault and success trees
- cause-consequence diagrams.

Further details of these can be found in Appendix C.
5.5 Data quality and integration

Good quality information is important in order to make informed decisions about the current level of risk. However, there are often deficiencies in the available data due to factors such as constraints in data collection systems and errors in the database, including incorrect recording of the location where crashes occurred. Crash databases are comprehensive in the collection and recording of crashes involving fatalities, but those involving lower severities often go unreported or are inaccurate in terms of location and orientation of vehicle movements. In some instances, the data collected may be based on subjective judgement.

It is therefore important to know how much reliability can be placed on data to enable informed decision making, and to work towards improvement where deficiencies are identified. These limitations can have direct implications on the successful management of risk. As an example, crashes attributed to the wrong location may direct funds to the wrong site, and lead to the problem not being addressed. There is a need for active management of data quality to improve decision making.

5.6 Cost effective data collection

There is obviously a wealth of data that could be collected to enable decision making about the level of risk. However, there are costs associated with data collection, both in financial and human resource terms. Therefore, there is a need to prioritise the data collected. The decision as to whether data are collected should be based on risk management. The question that needs to be asked is whether the availability of the data item could assist in analyses which could lead to preventing something from happening that would have an adverse impact on the objectives identified at the outset of the risk management process. If it will, then data collection will most likely be required.
6. Evaluating and Prioritising Risks

6.1 Introduction

Once risk levels have been identified, there is a need to evaluate and prioritise these for treatment purposes, as there are usually limited resources available with which to reduce risk. This prioritisation needs to take place with reference to the internal and external context, and especially in relation to the available level of funding. It is also important to prioritise risks with reference to the original objectives and to consult with all relevant stakeholders about the prioritisation process, and the outcomes from it.

This section provides guidance and examples to enable practitioners to effectively evaluate and prioritise risks.

6.2 Prioritising risks

One of the overall aims of risk management in the road safety context is to reduce trauma, and to do this in the most cost effective way. Given limitations on budgets, it is important to determine which interventions will produce the greatest savings in casualty numbers and severity. In many cases risks may be identified, the treatment of which would be at the expense of other more serious risks. As identified earlier, there are several sources of information relating to risk, including blackspot analysis, information from pro-active approaches (such as road safety audit), maintenance programs and public feedback. Each of these sources needs to be used in the process of prioritisation for later treatment.

Blackspots, routes and areas are perhaps the easiest of risks to prioritise, and there are well-established techniques available for this task. Other types of risk are more difficult to prioritise, although there is an emerging array of location-specific and network-level tools available.

6.2.1 Evaluation based on historic data

The most commonly applied technique to evaluate existing crash locations is to assess historical trends in data (including blackspot analysis and other techniques described in the previous section). This involves comparison with existing crash numbers (or crash rates, or the social cost of these crashes) over the network. However, evaluation also requires knowledge of expected reductions at the locations if they are treated. Predicted reductions in crashes from proposed treatments are calculated to provide input to a benefit cost analysis at each site. Sites can then be compared, and the most economically advantageous set of sites and interventions programmed for remedial work. For further discussion on this issue, see Appendix D, or for more detailed coverage, see Austroads (2004).

This process implies some knowledge about those sites that can be most effectively treated. Sites with high crash rates or social cost that have multiple causes of crashes may be more difficult to treat than sites with a lower social cost but greater commonality in crash types. Treating sites with a common crash cause where all the crashes are broadly similar may produce a higher reduction in social cost for the amount spent, although this will vary by site.
In addition to the cost benefit approach, intervention levels are sometimes used when prioritising sites for treatment. Intervention levels (along with levels of service) are mainly used in maintenance programs, but have relevance to road safety. As an example, surface condition, and the level of skid resistance may be subject to periodic assessment. Once the pavement condition deteriorates to a pre-determined level, remedial action is programmed. This level may vary as a result of geometric design elements (particularly horizontal and vertical alignment), traffic volume, rainfall, or road environment (including speed environment), and at hazardous locations such as intersections, or prior to pedestrian crossings. A lower intervention threshold is typically used in some environments as skid resistance is more important, and plays a greater role in safety at these locations than it does at others. Intervention levels help us to prioritise remedial treatments to get the maximum benefit from limited budgets.

6.2.2 Evaluation where there is little historic data

In the case of risks identified through pro-active assessment (such as network level assessments of risk, or road safety audit), or with sites and treatments suggested by elected members or the public, there is often little crash data to help with prioritisation. Because of this, prediction about future crashes is difficult. However, given that the majority of crashes on the road network fall outside what would normally be defined as blackspots, there is a need to address such locations in order to reduce overall road trauma.

The Road Safety Risk Manager (RSRM) is a tool that may be used in these circumstances to help assess risk and predict savings at locations or for different treatment types. Appendix E provides further details on this tool, while Section 9 includes practical examples where it has been used successfully.

6.2.3 Comparison between risk types

Although there are tools available to prioritise risks within each of these sources of information (i.e. comparing blackspots and prioritising for treatment), it is much more difficult to prioritise risks across a variety of data sources, for instance blackspot sites and recommendations from road safety audit. In Australia, the Department of Transport and Regional Services (DOTARS, 2005) suggests that recognition needs to be given to both blackspot and pro-active approaches, and suggests a proportion of safety treatments for each approach:

… the National Black Spot Programme also recognises that there are road locations which could be considered as ‘accidents waiting to happen’. Therefore, up to 20% of programme funds may be used to treat sites where road traffic engineers have completed a "Road Safety Audit" and found that remedial work is necessary. This allows an opportunity for proactive safety works to be undertaken before casualties occur.

In some locations there are fewer blackspots, and crashes are more scattered across the network (for instance on rural roads and in some local government areas). In such locations a higher proportion of funding on proactive safety works may be appropriate.

RSRM is an effective tool in prioritising pro-active approaches against more traditional blackspot treatments. As an example, this tool can be used by authorities to objectively assess public feedback (e.g. requests for installation of pedestrian crossing facilities) against other treatments highlighted from traditional blackspot programs. If the request for treatment falls short of risk reduction that may be gained from other expenditure, practitioners have a valid reason that is objective, transparent and documented with which to reject such requests.

6.3 Practical examples

Practical examples of road network risk assessment tools are provided in Section 9. These include:

- VicRoads guidelines for ‘Run-off-road’ program development
- Queensland Main Roads and the LGAQ Roads Alliance Road Network Safety Assessment Tool
• Queensland RISC software tool
• New Zealand economic model for resource allocation
• New South Wales network crash rates
• AusRAP – Road Protection Score
• UK SafeNet
• New Zealand RISA
• Western Australia CRASHtool
• Australian ALCAM
7. The Treatment of Risk

Just as there are multiple causes of crashes, there are multiple ways in which these causes can be treated. Some of these treatments are more effective than others making availability of relevant information on risk reduction important. Selection of treatments should be based on sound evidence, as measures that may appear to be potentially effective to the casual observer may have little impact on safety or, in the worst case, may actually lead to increased risk.

When treating legal risk, relevant local advice needs to be sought. For treatment of risks associated with adverse public opinion, there is a need to formulate relevant strategies, and this can be done in association with public relations personnel.

When treating the risk associated with road trauma, there are a number of ways that authorities can decrease the level of risk. These include:

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

In terms of solutions to the risk related to exposure and consequences, remedial treatments could be viewed as:

- elimination - remove the hazard
- substitution - use a safer option
- engineering controls - in terms of design modifications
- isolation - where the hazard is removed from direct influence
- administrative controls - including educational initiatives, speed limits, licensing, drink driving laws, or personal protective equipment – for example vehicle improvements (air-bags, electronic stability control etc.).

Additionally, the Haddon Matrix and Safe System may be used to formulate countermeasures based on human, vehicle and road related issues (including speed), and how these can influence safety before, during and after a crash.

Of greatest relevance to most authorities is the effect on risk from changes to the road environment. Through the monitoring of engineering based measures, information exists on the level of reduction that can be expected from measures in different road environments.

A wide variety of engineering-based remedial measures are available to treat road safety risk. It is beyond the scope of this guide to discuss these and the reader is referred to Austroads (2004). In addition, the notes on administration for the federal black spot program have a treatment crash reduction matrix showing expected crash reductions for various treatments. Most state road authorities have similar and generally expanded crash reduction information for state blackspot programs.

Other tools are currently being developed that will be of assistance in the treatment of engineering based risk. Austroads is currently developing the Road Safety Engineering Toolkit. This is designed to provide practitioners with easy access to best practice road safety information on engineering treatments. The main focus of this is on effective low-cost treatments for common problems, and it aims to assist practitioners in issue identification, potential solutions and appropriate applications for different treatments.
Once treatments have been developed for each of the risks, a treatment plan should be produced. This should include details of how the risks will be treated, who will be responsible for treatment of each treatment type, and what the expected outcomes are.
8. Monitoring and Review

Ongoing monitoring and review at all stages of the risk management process are required to ensure that the treatment plan is being met when implementing treatments, and that lessons learned from the process are recorded and included in future risk management. Measures may have both positive and negative consequences, and it is important to assess these to help refine future treatment options, and to minimise any negative factors. Monitoring is not only a useful source of information within the authority for use at a later date, but is also potentially useful for other authorities.

In addition, it is important to recognise the impact of changes in an organisational context (either in relation to internal or external factors), for instance in levels of funding, legislation or overall strategic policy. Treatment plans will need to be reviewed and altered where appropriate as the result of such changes.

A number of authorities monitor the success of road safety treatments based on changes in crash numbers. This typically involves evaluation of crashes before and after the treatment, and attributing changes in crash numbers or rates to that treatment, although it may also involve monitoring changes in behaviour (such as compliance with speed limits). Statistical techniques are often applied to determine the effect of the treatment, and where possible appropriate control sites should be used to help counter any effects caused by external factors. Care also needs to be taken in ensuring that changes in traffic volumes are taken into account when evaluating some types of treatments. Further details on these issues can be found in the guide to Treatment of Crash Locations (Austroads, 2004).

A number of authorities have created monitoring databases to assess the effectiveness of road engineering treatments. At the most basic level, a monitoring database should include records of what problem existed that prompted the need for action, the actions that have been taken, the location, and the date that the actions were started and completed. Ideally, this information should be linked to information on crashes both before and after treatment. Any other relevant information that has been collected should also be included (for instance, before and after speed data for a speed camera site).

Examples are given in Appendix F of the UK MOLASSES database and the New Zealand Crash Analysis System (CAS).
9. Case Studies

A number of case studies are provided in this section to illustrate examples of risk assessment and management in the road safety context.

9.1 VicRoads Guidelines for ‘Run-off-road’ program development

Run-off-road crashes represent a significant issue on Australasian roads. Recent research from Victoria highlighted the following:

- 45% of casualty crashes in rural areas in Victoria are run-off-road crashes
- over 60% of these involve a vehicle striking a fixed object
- 80% of fatal run-off-road crashes in rural Victoria result from collisions with fixed objects.

In recognition of the significant trauma experienced on Victorian roads as a result of run-off-road crashes, funding was sought for a significant program to address run-off-road crashes on high-speed rural and outer metropolitan roads, commencing in 2004/2005.

The purpose of the research was to provide guidance to VicRoads regional staff in the preparation of submissions for the funding of projects under the Safer Road Infrastructure initiative as part of the Road Safety Program.

The process

1. identify the most hazardous road segments based on casualty crash rates per km
2. identify the highest risk locations within these segments based on a risk rating process building on work developed as part of the Road Safety Risk Manager
3. rank treatments using the Road Safety Risk Manager
4. rank segments based on cost-effectiveness in reducing casualty crashes (BCR).

The risk rating process identified in step 2 considered issues related to the likelihood and severity of a run-off-road crash. To ensure the safety of personnel undertaking the surveys, the process was designed such that digital imaging records of the road could be used to undertake the assessments.

A spreadsheet was developed to assist in the assessment process, and a training program was delivered to all regional staff.

9.2 Queensland Main Roads and the LGAQ Roads Alliance Road Network Safety Assessment Tool

The Road Network Safety Assessment Tool was completed by ARRB in collaboration with Queensland Main Roads and the LGAQ Roads Alliance. The aim of the Road Network Safety Assessment methodology is to provide Regional Road Group (RRG) members (combined state and local authority) with a sound basis to pro-actively identify road safety issues across their network, and ultimately develop a well prioritised works program to address the concerns identified. The process serves two main purposes:

- assist the RRG member to ensure investment is directed in a way that saves the maximum number of lives, and maximises the reduction in injury and property damage crashes
- assist the RRG member in meeting duty of care in relation to legal responsibilities.
The process

The process developed for the Roads Alliance involves two stages. A network level risk assessment is completed to focus attention on high risk sections of road where the risk of crash and the associated treatment of that risk is expected to provide the greatest return. The high risk sections are then investigated in greater detail to locate specific hazards and the preferred treatment option. The individual treatments are then analysed to prioritise all potential treatments across the Council or RRG to ensure the highest value projects are completed first. This will ensure the greatest reduction in road trauma from the total program investment.

The network level risk assessment has been designed to provide the RRG and its members with a picture of high risk sections across the network. The ‘Network Risk Score’ is based on the research behind the Road Safety Risk Manager and includes components related to the following:

- road type (urban intersection, urban mid-block, rural intersection, sealed rural mid-block and unsealed rural mid-block)
- road elements impacting crash likelihood (e.g. horizontal alignment, lane width, shoulder width, delineation, skid resistance/surface condition, sight distance, turning provision, pedestrian provision)
- road elements impacting severity (speed, roadside environment, type of crash).

ARRB also developed a spreadsheet tool to provide RRG members with simple means to calculate the Network Risk Score.

Location and assessment of high risk sites can be undertaken by either driving the road network, or through the use of geo-referenced digital video. The demand on resources is kept to a minimum by rating only those sections that include elements (such as those detailed above) that exceed a certain condition level, referred to as a ‘safety trigger’. For example, in relation to horizontal alignment, the safety trigger is only fired when the safe curve speed (e.g. the signed advisory speed of the curve) is less than 70 km/h, and the normal approach speed is estimated to be 80 km/h or greater. Depending on available resources and the commencement condition of their local network, RRGs may choose to refine these triggers.

On completion of the rating for each section that has been triggered, the RRG member is able to map risks across the network and identify those high priority sites for further investigation and potential treatment (see Figure 9.1 below).

The process developed allows individual RRGs to undertake some local refinement of models to ensure local conditions and resource availabilities are accounted for.

Following the identification of the high risk sections, authorities can then identify potential remedial treatments and/or increased maintenance standards to help limit the risk. Projects can then be prioritised using the Road Safety Risk Manager to develop a road safety works program ready for implementation.
9.3 Queensland RISC software tool

Queensland Department of Main Roads has developed a Roadside Impact Severity Calculator (RISC) software tool which is aimed at prioritising roadside hazards for removal (see Douglas and Spencer, 1999). It specifically deals with roadside hazards, as run-off-the-road crashes account for greater than twenty per cent of all crashes in Queensland. A three step procedure is involved that includes:

**Hazard identification**

Hazard identification is used to evaluate the hazard potential of roadside objects. This considers variables such as clear zone, location of hazard and crash history. Clear zone rules of thumb or AASHTO (the American Association of State Highway and Transportation Officials) guides are used in the identification process.

**Risk analysis**

Risk analysis is performed to evaluate the risk posed by the hazard. This is based on AASHTO guidance and considers road environment variables, traffic volume and object attributes. These inputs are used to calculate an encroachment frequency (a base encroachment rate multiplied by traffic volume, curvature and grade factors). The object collision frequency is then calculated by considering lateral encroachment probability, encroachment angle, vehicle ‘swath’ width, encroachment frequency and object lateral offset and width.
Assessment of remedial measures

Appropriate treatment options are then identified. Benefit cost analysis is then used to rank treatments to get the best return for limited funds. Other factors, such as environmental or social issues, may also influence the order of ranking.

9.4 New Zealand economic model for resource allocation

The Land Transport Safety Authority (LTSA) has developed an economic model for road safety resource allocation. The model attempts to overcome the difficulties of allocating resources to individual projects as they are approved, by allocating resources to regions and to types of intervention so that overall efficiency is optimised. One version of the model, which has been provisionally applied, concentrates on road safety enforcement by police patrol. The model may have wider application for spending on road safety engineering, enforcement and some educational programs.

Marginal analysis was used to systematically identify the part of the network that offered the greatest benefits. This involves the analysis of spatial units (points, road segments or zones), calculation of benefits and calculation of the cost of different interventions. The question of interest was how much of each intervention should be carried out on each part of the road network. From the results it can be seen where resources are over- and under-provided. While providing resources still results in benefits for that area where over-provision occurs, the resources will not do as much good as they could do elsewhere. Application of the enforcement model to New Zealand predicted a fall in social cost by ~NZ$18 million (the saving of about three fatal and 75 reported non-fatal injury crashes) if resources were allocated according to the model.

9.5 New South Wales network crash rates

In New South Wales, the RTA has calculated crash rates at a network level for various road stereotypes, focusing on rural roads. The project aims to determine the relative priority of road links by identifying current and potential problem locations for analysis. A spatial database was set up linking road crashes with other roadway attributes and parameters.

Crash data was collected and stored electronically and geo-referenced. Road attributes were collected through use of GispiCam imagery data collection.

Thirty-four roadway cross sections with similar design characteristics and layout (road stereotypes), were selected. These stereotypes covered single and dual carriageways according to number of lanes, ranges of lane width and ranges of shoulder width. Average historic crash rates were then calculated for each stereotype.

Within each stereotype, different sections have their own additional attributes. These attributes (e.g. centre line marking, horizontal curvature, speed zone, traffic volumes) were analysed to determine what effect individual attributes had on crash rates for each stereotype. For instance, the model calculated that for two lane divided sections with a painted median, the average crash rate is 9% lower than the average crash rate for two lane non-divided sections.

The model allows the identification of problems on a route basis and the effect of remedial treatments to be considered. Subsequent to identification and suggested solution, economic analysis and cost-benefit can be applied to prioritise treatments.
9.6 AusRAP – Road Protection Score

The RACV, on behalf of the Australian Automobile Association engaged ARRB to develop and pilot a methodology to assess the inherent safety of a road network based on the engineering features of that network. The network level road safety risk assessment process is designed to form part of the AusRAP (the Australian Road Assessment Program) initiative.

The pilot provides an initial working model for the key stakeholders to evaluate the feasibility, potential applications and presentation methods associated with the AusRAP models, and facilitate its communication to the public.

The project involved the development of a network level road safety assessment methodology, building on existing work completed by ARRB and Austroads as part of the Road Safety Risk Manager research.

The results of the pilot study are summarised in Figure 9.2. The key measure used to assess risk was the Network Road Safety Score (NRSS), based on the proactive assessment of a range of road engineering features. The lower the NRSS, the safer the road.

As an indication, the first 110 km of the Western Highway is divided carriageway and as such scored a lower level of risk. The risk on the undivided sections increased, with fluctuations in risk evident along the entire road as road features (such as roadside hazards, alignment, cross-section, intersections etc) varied in condition.

Figure 9.2: AusRAP Pilot Study: Network Road Safety Scores

Following the completion of the pilot study the motoring associations have now publicly released the findings (see eg www.Ausrap.org), and further work is planned in the development of the Network Road Safety Scores in the near future. The extension of the AusRAP research has been identified as a priority action in the National Road Safety two-year Action Plan.
9.7 UK SafeNet

The Transport Research Laboratory (TRL) has developed SafeNET (Software for Accident Frequency Estimation for Networks), a software package to assist traffic engineers in the design of safer road networks. Research has been conducted to develop models to predict crashes, and to apply these models for an area-wide assessment. The SafeNET software is designed to provide a rapid assessment of the effects of potential network management changes and how changes in junction design, form of control and traffic assignment affect the crash frequency on the network.

The software allows users to build their network on the screen (Figure 9.3). Data can then be added for each network feature.

Figure 9:3: Screen representation of SafeNET road network

From this information, details of the predicted number of crashes can be obtained.

‘Accident predictive models’ have been developed for typical intersection types. The model estimates the number of crashes that can be expected on average, given information on traffic flow and the design of the intersection or link.

Total junction or road link crash frequencies can be obtained by entering information on vehicle flow, pedestrian flow and site characteristics. This software is designed to interface with assignment programs to combine predictions of how traffic will re-route, and estimates of resulting crash patterns (Department for Transport, 1999). TRL has recently released version 2 of this software.
9.8 New Zealand RISA

Land Transport NZ is developing an objective assessment tool in order to provide an indication of the performance of Road Controlling Authorities (RCAs) with respect to road safety, and to assist these authorities in improving road safety by identifying those features that make the greatest contribution. As a further aim it is hoped that the tool will be helpful to those managing the networks. Road Infrastructure Safety Assessment (RISA) grew from early work in New Zealand on safety auditing of existing roads. However, given the subjective nature of this earlier method for assessment, a more objective approach was sought.

The RISA system examines the road context (including traffic volumes and terrain) and features of the road. These features are then compared against an assumed road average for that road type. The model multiplies the length of features on the road being assessed by the crash rate for that feature. Road features that contribute to risk are currently added to form an overall road rating. The assessment includes both a desk top study (comparing the road section with the reference road section), and an inspection to assess road features (and the length of these features). Field sheets are used for the four broad areas of road cross section, alignment, surface and intersections. When assessing the road, lengths are recorded where the features fall above or below a reference value. Lengths below the reference are attributed with a higher level of risk. Risk Features Scores are calculated for each of the feature types (including a measure of length for the section assessed), and combine to form a ‘Mid Block Risk Score’. This is then multiplied by factors for road type and terrain type (which carry different degrees of risk), and by traffic volume. The end product is the Factored Risk Score. This score is used for comparison purposes only, and has no absolute meaning.

The results from RISA are used at the policy or network wide level, and are not designed to treat specific locations. Specific ‘themes’ are identified that may require some program of work. In addition, the tool can be used to make comparisons before and after the implementation of measures to assess the improvement in safety in these themes.

A peer review identified a number of issues about the RISA methodology, and these are being addressed. The most important is the issue of double counting whereby some of the assessed features are embedded in other components of the methodology. RISA is still at the development and testing stage, but it appears to have potential in the management of risk at the strategic level. RISA has been developed for rural roads only, although work has recently started to develop a RISA for urban roads.

Further details on RISA can be found in Appleton et al. (2005).

9.9 Main Roads WA CRASHtool

CRASHtool is a software tool that is designed to assist in the analysis of reported road crashes on the Western Australian public road network. It provides an interface with the WA crash data system (the Integrated Road Information System, or IRIS) and includes features that assist in the identification and diagnosis of hazardous locations. It also has the capability to analyse the safety effectiveness of multiple countermeasures at a location, and to rank and prioritise results from this analysis. CRASHtool is also integrated with black spot program nomination processes.

Development of CRASHtool began in October 2002, where it was initially intended as a tool to assist in fatal crash investigations. However, it is now used more widely including road network analysis and works program prioritisation. Reporting is intended to assist with crash analysis investigations, research and black spot submissions (Figure 9.4). The tool can be used to:

- diagnose performance problems at a location by comparing crash distribution with network average crash patterns
- prepare a collision diagram at intersections
- rank possible countermeasures in decreasing order of net present value of crash costs to enable treatment selection
• assess trends in crashes at a location using a crash factor matrix
• model up to four countermeasures simultaneously at a location and prepare cost benefit calculations.

Figure 9.4: Example of report output from CRASHtool

<table>
<thead>
<tr>
<th>Crash Nature</th>
<th>CRASH codes</th>
<th>This study area</th>
<th>Network average</th>
<th>Flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear End</td>
<td>31,32,33,35,61,82</td>
<td>31</td>
<td>55</td>
<td>Significantly under-represented</td>
</tr>
<tr>
<td>Head On</td>
<td>21,51</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sideswipe</td>
<td>23,24,25,26,34,35,36,37,38,39,42,53,54,64</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Right Angle</td>
<td>11,12,13,14,15,16,17,18,19,20,47,49,49</td>
<td>15</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

It is intended to continually refine CRASHtool with proposals to include information on traffic volume and composition, pavement geometry and condition, and speed zone information.

9.10 ALCAM

The Australian Level Crossing Assessment Model (ALCAM) is used to assess the level of risk at level crossings throughout Australia. The ALCAM model was initially developed by the Queensland Government and is now managed by a national reference group which continually monitors its relevance and reliability. ALCAM produces a risk score for a level crossing based on the physical characteristics of a level crossing and the existing warning and control devices that have been installed.

ALCAM provides a relative risk rating (comparative to other crossings) rather than assessing the safety of a crossing in a stand-alone manner. The model is also useful in the identification of the key characteristics that contribute to risk at level crossings.

A risk score is calculated based on the risk posed to each road vehicle driver that approaches the crossing, assuming that the driver exhibits appropriate behaviour, and is not an overall measure of the safety of the crossing. Scores are not used to determine whether a crossing is ‘safe’ or not, but rather as an indicator on how the risk score for a crossing would compare with the level of risk that may be acceptable at other crossings with a similar traffic and road environment profile.
The risk score is calculated by assessing the traffic level (average daily train movements multiplied by average daily road vehicles). This is then modified by an Environmental Factor, which acts as a multiplier to address the severity of the consequences of an incident based on factors such as the type of road/rail traffic, road approach alignment and road traffic speed.

Risk scores that fall below the ‘Installation Score’ indicate a level crossing risk is likely to be within acceptable limits and remedial work to address the identified risks is probably not required (although the condition and use of the crossing must be monitored). Risk scores that fall between the ‘Installation Score’ and ‘Intervention Score’ may have hazards that need to be managed, while those above the ‘Intervention Score’ are likely to require priority attention to reduce the level of risk.
References


ATSB 2004b, Serious injury due to road crashes, Australian Transport Safety Bureau, Canberra, ACT.


Sarre R 2003, ‘Liability in negligence and the High Court decisions in Brodie and Ghantous: where to from here for road authorities’, Road and Transport Research, vol.12, no.4, pp.3-12.


Appendix A  Managing Risk Associated with Road Users

Managing risk associated with road users is a duty which road authorities undertake in partnership with police, the court system, and health sector. At present, there is no comprehensive system of risk management pertaining to road users, but rather a range of separate initiatives which have emerged over the years. The principal ways in which risk associated with road users is managed are as follows:

A.1  Entry to the system

In Australia and New Zealand, road and/or transport authorities have a duty to ensure that all persons in charge of motorised vehicles, beyond a very low threshold, have the requisite sensory, motor and cognitive abilities to manage their vehicle, and that they have acquired the requisite knowledge regarding road rules and operating procedures in traffic, along with the practical driving skills to be able to drive safely.

A.1.1  Fitness to drive

Austroads has published a comprehensive guide on assessing fitness to drive which covers all aspects of physical and mental ability to drive. This is intended as a guide to medical practitioners and other professionals who are called upon to make an assessment as to whether a person is fit to drive or not. It contains separate criteria for the drivers of commercial vehicles, to whom additional criteria are applied in recognition of the greater potential for harm when large vehicles are involved in crashes.

Eyesight is the way in which the fitness to drive guidelines impact most road users. The Austroads guidelines require basic standards for visual acuity and visual field. Most jurisdictions back this by undertaking screening for static visual acuity at the time of the first licence application, using the Snellen eye chart or an equivalent device. Some jurisdictions test only when the first licence application is made, while others repeat the screening on each licence renewal. At present, South Australia and Queensland do not carry out any screening, placing the onus on the individual to declare any visual abnormalities, with Queensland currently in the process of considering whether to re-introduce some form of screening. Only New Zealand routinely tests for both acuity and visual fields, using special testing apparatus.

Persons who have sensory deficits, or who have movement or strength limitations, can often be helped to drive safely by the installation of suitable driver aids such as additional mirrors or video cameras, steering wheel handles, and hand-controlled accelerators and brakes. There is a well-developed body of expertise and a workforce capable of applying it to assist with these problems. The role of the road or traffic authority is in ensuring that persons with abilities are properly assessed, that they are given sound advice regarding which aids are necessary in their particular circumstances, and that conditions applied to the licence of a person with a disability are appropriate.

A.1.2  Driving licences

Road and transport authorities have a responsibility for ensuring that drivers have the required knowledge of rules and operating procedures and that they have acquired a sufficient degree of practical driving skills before being allowed to drive independently.
It is mandatory for drivers and riders in all jurisdictions to pass a theory test before they are issued with a Learner’s permit which permits them to drive under supervision. The theory test covers a range of issues, including road rules and priority in different situations, recognising and understanding road signs and markings, understanding roadworthiness requirements, alcohol and drug prohibitions and restrictions, and fatigue. Before being allowed to drive unsupervised, candidates are required to pass a practical driving test, in which the candidate is exposed to a range of typical driving situations. However, given its relatively short duration, it is limited in terms of what skills can be tested and in terms of the depth to which these skills can be tested. Following passing the basic test, drivers are then placed on a probationary licence, the conditions of which vary among jurisdictions. Some jurisdictions now include a hazard perception test as part of the migration to full licence in an effort to encourage drivers to acquire the skills of ‘reading the road’ characteristic of mature, low-risk drivers.

A.1.3 Licences for other vehicles

Operating a motorcycle, rigid truck or bus, or articulated truck requires a licence for that particular class of vehicle. Obtaining these licences requires a practical driving test which assesses skills in handling the class of vehicle in question.

A.2 Removal from the system

Complementing control over entry to the system as a means of managing the risk associated with drivers is the responsibility for removing drivers from the system whose driving poses an unacceptable threat to others and themselves. This may come about through injury or disease, particularly those conditions associated with old age, or may come about through persistent serious offending.

A.2.1 Fitness to drive

In the event of serious injury or debilitating illness changing their capacity to drive, individuals are obliged to notify the relevant authority of their changed capacity to drive. A thorough-going assessment is then carried out to determine whether and under what conditions the individual can continue to drive, relying on the body of expertise described in the section on fitness to drive.

Although the same obligations apply in the case of age-related conditions, termination of licence on these grounds tends to be more contentious. The onset of the conditions may be gradual, so that the individual has little awareness of diminished capacities. The same conditions which affect driving may affect other aspects of awareness and decision-making, making it hard for the individual to make a reasoned decision. Medical practitioners are placed in a difficult position as drawing attention to an individual’s problems with driving may have implications for the therapeutic relationship. Road authorities generally have a three-pronged approach to this issue. First, they provide advice to older drivers about how to manage trip choice and aspects of their driving to minimise risk. Second, they provide advice and support (usually indirectly to carers and others intimately involved with older people) regarding surrendering of licences when the individual feels they can no longer cope with driving - this is the preferred way for ending a driving career. Third, they will cancel a licence if the individual is no longer capable of driving safely.

A.2.2 Serious and repeat offenders

Responsibility for removing serious and repeat offenders from the road system is a responsibility which is exercised jointly with police, licensing authority and the court system. Police are generally responsible for detecting and prosecuting offences (although road and transport authorities do have a role, especially where heavy vehicles are concerned). Court systems are responsible for determining guilt and applying penalties. Although many serious offences and repeat offences carry automatic periods of disqualification, courts may have discretion to waive a period of disqualification under certain circumstances, and may have considerable discretion over the length of the disqualification.
Removing an individual from the driving system is generally seen as a form of punishment. However, it is also a risk management tool, provided it can be enforced. Removing the driver from the system prevents the driver posing a risk to other road users.

An inherent problem of this approach is that, in societies like Australia and New Zealand, the primary function of courts is to consider evidence of offences committed, make determinations of guilt or innocence, and decide penalties. Their core concern is justice for the individual, not risk management. Offenders are therefore likely to be given the benefit of the doubt when it comes to imposing disqualifications or deciding on their length.

A further weakness of the system is that many drivers who are disqualified frequently take the risk of driving while disqualified. Although there are provisions for severe penalties, including imprisonment, they seem to be imposed only after repeat offending. This is further exacerbated by a low probability of detection for driving whilst disqualified. In this context, it is perhaps not surprising that the management of risk posed by road users has not been more successful.

A.3 Emerging possibilities

New technologies open up new possibilities for controlling the risk posed by road users.

A.3.1 Controlling access to the road system

Technology to permit only qualified drivers to start and operate vehicles is in an advanced prototype stage (Goldberg, 1999). It consists of a ‘smart’ licence which electronically stores personal details, licence classification, conditions applying to the licence, and possibly a record of some biological identifier to ensure that the licence can only be used by the person to whom it was issued. A reader is mounted in the vehicle, interlocked with the ignition system. It would prevent a vehicle being started by anyone other than a qualified driver with a current licence to drive that class of vehicle. The system would also keep track of who was driving the vehicle and when. Obviously, it will take several years before this technology becomes sufficiently widely disseminated through the vehicle fleet for it to be an effective means of reducing access by unlicensed or unqualified drivers.

While it would be naïve to think that the combination of smart licence and ignition-interlocked reader would eliminate driving by disqualified drivers, it would certainly make it much more difficult, and hence make orders relating to disqualification much more effective.

A.3.2 Eliminating possibilities for offending

Existing and emerging technologies have the potential to greatly reduce certain types of offending, including some offences that currently pose the greatest risk in road safety terms. Three developments are of particular interest.

Alcohol Effective alcohol ignition interlocks have been available for several years. Trials are currently under way in a number of jurisdictions, and Victoria now has provision for alcohol interlocks as part of the system for dealing with drink-drive offenders. Candidates for the trials are generally people who have had multiple serious alcohol offences. By requiring a serious offender to have an alcohol interlock fitted until they can meet a reasonable criterion for responsibility in relation to alcohol and driving, the licensing authority/court system can largely remove the risk associated with that individual’s patterns of driving after drinking.
**Speed** Effective speed limiters have been available for years. The risks associated with excessive speed by persistent open road speeders could be substantially reduced by requiring these offenders to have a speed limiting device fitted to any vehicle they drive, operating along the same lines as an alcohol interlock. However, this would not affect the problem of speeding on urban roads. Prototype intelligent speed advisory systems, which advise drivers if they are exceeding the speed limit on a particular length of road, are being trialled. Mandatory fitting to the vehicles of drivers who persistently speed in urban areas may be effective in controlling their behaviour. There would also be the option of producing intelligent speed control systems, which limit the maximum speed in accordance with the limit which applies at that point.

**Seat belts.** Use of restraints is at high levels in Australia and New Zealand, but fatalities involving unrestrained vehicle occupants are disproportionately high. Seatbelt reminder/interlock systems already on sale in some markets could improve this. Further advances coming on stream include prototype systems which will play increasingly louder reminder messages if a vehicle seat is occupied but the matching seat belt is not fastened. If required in all vehicles, such systems can be provided at low cost. While they would not completely eliminate non-wearing, they are likely to reduce it considerably.

The general principles for risk management outlined in the main document can be applied to the management of risks associated with road user behaviour. However, it appears that this has not been done in a systematic way to date. In order to manage risk effectively, the basic stages of risk identification, analysis, evaluation and treatment for risks associated with road users need to be undertaken.

**References**
Goldberg F 1999, ‘An electronic driving licence when used as an ignition key could save thousands of lives’, *National Conference on Injury Prevention and Control, 3rd, 1999, Brisbane, Queensland, Australia*, University of Queensland, Centre of National Research on Disability and Rehabilitation Medicine, Herston, Qld, pp.43-7.
Appendix B  Data Sources

There are a large variety of data sources that can be used when assessing levels of risk. This appendix highlights some of these, although there may be others that will need to be considered, depending on the local context and objectives.

The most obvious source of data of relevance in the road safety context is that from crash databases. Crash data are an effective tool in assessing crash causation, including factors relating to human, vehicle or road related issues. Crash data is collected by the police, either at the scene of the crash, or subsequent to this. All Australasian jurisdictions have agreed to work towards a minimum common dataset, although in many cases, more detail than this minimum is already collected. This information is integrated into a crash database for ease of accessibility and analysis.

However, there are other relevant sources besides police based crash data that could be drawn upon. For example, information on crashes is available from hospital data (which may be of use when examining crashes which are generally under-reported, including pedestrian and cyclist crashes) and insurance data. However, these additional sources of data are often difficult to access, and police reported crash data is often used for this task.

Pro-active assessments of safety also provide a valuable source of information. Methods including road safety audit (see Morgan, Epstein & Drummond, 2002) or network based assessments (see section 9 for examples of these) add useful information on potential risks. Further information is available from public feedback and consultation on specific crash sites. This may highlight additional sources of risk (although whether this is actual or perceived risk will need to be determined).

Information from asset management and road inspection will also be of relevance, as issues highlighted through these processes can often provide information on level of risk (for example relating to road surface condition). For further information on these issues, refer to Austroads’ Guide to Asset Management.

Traffic volume data is often used as a source of data, especially in conjunction with crash numbers to provide crash rates. This technique is particularly useful in helping identify routes, areas or crash types that fall above the average expected. Similarly, pattern analysis can be undertaken to identify common crash types for treatment (for instance drink drive, speed, fatigue, and run-off-road crashes). Vehicle classification data is also sometimes used to identify vehicle specific issues.

Enforcement and monitoring data, including measurement of vehicle speeds, or helmet and seat belt wearing rates may also be of use when assessing the effects of some treatment types. This information can be used to identify safety issues, and also for monitoring purposes (see Section 8).

When assessing the level of risk associated with the legal context, there is a need to consider the appropriate legislation, as well as legal precedents. This is a constantly changing area, especially in Australia at present. Consultation with appropriate legal advisors will most likely be required.

References
Appendix C  Qualitative and Semi-Qualitative Analysis

Risk classification

Risks can be classified according to likelihood of occurrence, and consequences if they do occur. In cases where there is limited objective information, a qualitative approach can be taken. As an example, risks can be classified as to whether they are high, significant, moderate or low, as below:

![Risk Classification Table]

\( H = \text{High risk}; S = \text{Significant risk}; M = \text{Moderate risk}; L = \text{Low risk} \)

The level of risk may be attached to some form of action. For example, immediate action or senior management attention may be required for high risks. This approach is also useful as an initial screening before more in-depth analysis is undertaken.

Alternatively, a semi-quantitative analysis can be undertaken using the same qualitative scales as above, but applying numerical values. Risk can be ranked in ‘bands’ from low to high:

Linear ranking

![Linear Ranking Table]
**Fault and success trees**

In order to examine likelihood in more detail, a systems engineering technique, such as a fault tree can be used to assess probabilities of occurrence in more detail. The fault tree follows a path of undesired events (and the probabilities of those events, for example, on a per annum basis) to provide an overall likelihood of the particular fault being considered. Success trees operate in a similar manner although the results are based on the probability that an item is available and is therefore preferred by reliability engineers. Examples of the various methods are shown below.

**Fault Tree**

```
Fault Tree

Traffic Light Fails

Power Failure 2 p.a.
Fuse Failure 0.02 p.a.
Bulb Burn-out 3 p.a.

Power Surge 0.01 p.a.
Incorrectly set 0.01 p.a.
```

**Success Tree**

```
Success Tree

Traffic Light Available 0.947

Power Available 0.999
Fuse Operational 0.998
Bulb Operational 0.95

Fuse Available 0.999
Correctly set 0.999
```
**Cause-consequence diagram**

The cause-consequence diagram is an extension of the above models, where a series of factors can influence the occurrence of an event, and a series of factors affect the outcome of the event. The purpose of cause-consequence is to identify chains of events that can lead to undesirable consequences. Prior events could include driver, vehicle and environmental factors that may influence a crash. After factors could include roadside hazards or access to emergency services. A schematic example is shown below.
Appendix D  Benefit Cost Analysis

This appendix discusses some of the issues involved in conducting an economic appraisal. For further information relating to crash risk, full details on how to conduct an economic appraisal are presented in the guide to Treatment of crash locations (Austroads, 2004). For a more in-depth coverage on issues relating to economic appraisal, see the Austroads Guide on Project Evaluation (e.g. Tsolakis, Preski & Patrick, 2005).

The most common forms of benefit cost analysis used in assessing crash risk are the benefit-cost ratio (BCR) and Net Present Value (NPV). Both rely on information on benefits gained from the treatment (usually savings in crash costs which incorporates changes in the number and severity of crashes, and costs associated with implementing the treatment (including initial capital costs and any increase in ongoing operating or maintenance costs). The cost savings are often attributed over a number of years, and standardised costs for different crash types used). Future annual costs and benefits are reduced (or discounted) to the equivalent of present day values so as not to distort future dollar values.

BCR is the ratio of benefits over that of costs. A ratio of greater than 1.0 indicated that the project provides greater benefit than its cost. NPV is the difference between costs and benefits (costs are subtracted from the benefits), with a positive NPV meaning that the project is of benefit.

Below is an example from the Austroads Guide to Treatment of crash locations, and this in turn comes from Ogden, 1996.

The example is the installation of a roundabout in an urban area to address an intersection problem. It is assumed that the capital cost of the scheme is $20,000, and that there will be no change in vehicle operating costs, or vehicle flow through the intersection. There is currently an average of one adjacent approach crash per year (the associated crash cost for this was estimated at $42,000 based on Queensland Department of Main Roads data for 1998). It was assumed that a 70% crash reduction could be expected from the introduction of the roundabout. The appraisal period was 10 years, and the discount rate was 4% per annum.

In the ‘do nothing’ case, the annual cost of crashes would continue at $42,000 per year. With the introduction of the roundabout, we would expect an annual benefit of $29,400 (or a 70% reduction in the cost, based on a 70% crash reduction). A benefit is assumed over a 10 year period, and there is a need to discount this. At a discount rate of 4% per year, the present worth of $1 per year over 10 years is $8.11 (this can be calculated, or derived from discount tables). Multiplying the annual benefit of $29,400 by 8.11 provides a total benefit of $238,000. With an installation cost of $20,000, the NPV is $218,000 ($238,000 - $20,000), and the BCR is 11.9 ($238,000 ÷ $20,000).

It is also recommended that sensitivity analysis be conducted, for instance by varying the crash reduction percentage, or the capital cost of the scheme to determine the effect of any errors or variations in the assumptions.

References

Tsolakis, D, Preski, K & Patrick, S 2005, Guide to project evaluation: part 1: introduction to project evaluation, AGPE01/05, Austroads, Sydney, NSW.
ARRB and Austroads have developed the Road Safety Risk Manager (RSRM) to provide authorities with a powerful tool to manage, prioritise and track the status of road safety issues on their networks.

The process allows a proactive assessment of hazards without the need for existing crash data, or waiting for a crash to occur. The associated treatments can then be prioritised to develop a works program focussed on maximising the reduction in road trauma with the available budget.

Originally launched in October 2002, following five years of research and development, the software is in use by road authorities and consultants throughout Australia and New Zealand. The software allows the assessment and comparison of some 70 different road safety treatments including issues such as the duplication of a highway, intersection upgrades, guardrail and other roadside treatments, signage and delineation to name a few. The flexibility of the tool also allows for the assessment of design options in addition to hazards in the existing road environment. RSRM is being used in a wide variety of ways by authorities including the following:

- blackspot program prioritisation
- review of construction options and high-cost design options
- prioritisation of mass action programs for bridge approaches, skid resistance treatments, run-off-road crashes
- development of policies related to balancing environment and safety issues in regard to roadside vegetation
- road safety audit recommendations
- prioritisation of public complaints on safety issues
- development of road safety works programs
• assessment of safety related actions in relation to legal claims.

RSRM complements recent network safety assessment tools (e.g. see Queensland network tool in Section 9.2) by prioritising the projects identified as being of high risk.

The models behind the software also continue to be updated as part of extensive research on road safety engineering risk assessment being delivered by ARRB and funded by Austroads. The program of research will improve knowledge of road engineering risk and ultimately better target road safety funding to bring down the road toll.

The key components of the RSRM software include recording and analysis of the following:

• Exposure (number of vehicles and/or road users exposed to the hazard).

Most road authorities have traffic count data within their road management systems, or the volumes can be estimated from site visits or road use information.

• Likelihood (length of hazard, general crash risk at the location, the risk of the hazard and associated treatment and the risk of related road features at the site).

For the majority of locations the practitioner will have sufficient information from local knowledge, a photograph or video data to undertake the assessments. The relative risk models within the RSRM make it easy for the practitioner to determine the risk levels associated with various features. For example, when considering lane width, the RSRM provides the following risk levels:

<table>
<thead>
<tr>
<th>Lane Width</th>
<th>Relative Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.7 metre lane width</td>
<td>1.0</td>
</tr>
<tr>
<td>3.4 metre lane width</td>
<td>1.05</td>
</tr>
<tr>
<td>3.1 metre lane width</td>
<td>1.15</td>
</tr>
<tr>
<td>2.8 metre lane width</td>
<td>1.35</td>
</tr>
<tr>
<td>2.5 metre lane width</td>
<td>1.64</td>
</tr>
</tbody>
</table>

That is, on a road with a 2.8 metre lane width a driver is 1.35 times more likely to have a crash than on a road with 3.7 metre lanes.

Similar risk models are provided for all 57 deficiency types. All of the models are updated on a rolling basis as part of the ongoing Austroads research program to reflect latest knowledge and experience.

• Severity (speed and crash types likely as a result of the hazard)

Based on the hazard being assessed, the practitioner determines the crashes most likely to occur as a result of that hazard at that location. For example poor skid resistance at an intersection will most likely lead to rear end crashes and the possibility of adjacent approach crashes if a vehicle enters the intersection when the road is not clear. Where beneficial, a review of the crash history at a location may assist in determining the appropriate crash mix.

• Treatment details (initial cost, ongoing costs and treatment life)

Based on the treatment to be installed at the location, an estimate of the treatment cost, ongoing maintenance costs and treatment life is required. This information may be determined from previous contracts for similar treatments, standard schedule of rates, maintenance data or discussions with construction personnel.
The figure below provides a screen shot of a hazard and treatment summary from RSRM.

**Individual hazard and treatment summary form**

![Individual Hazard and Treatment Summary](image)

The figure below provides a screen shot of a hazard and treatment summary from RSRM.

**Individual hazard and treatment summary form**

![Individual Hazard and Treatment Summary](image)

A range of different reports have been tailored to suit all needs from detailed technical review, to management overview and budget analysis, including the multiple hazard and treatment report, and budget scenario analysis.

**Multiple hazard and treatment report**

**Multiple Hazard and Treatment Report**

**Summary**

*Report generated on 24 Jan 2003 16:59 by Bob Mahoney*

<table>
<thead>
<tr>
<th>Road Name</th>
<th>Hazards</th>
<th>Hazard Location</th>
<th>Hazard Risk</th>
<th>Proposed Treatment</th>
<th>Treatment Risk</th>
<th>Life</th>
<th>Initial Cost</th>
<th>Disc. Risk Reduction</th>
<th>Disc. Cost</th>
<th>Risk Cost Ratio</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Ave</td>
<td>Poor skid resistance around the sharp corner</td>
<td>Near Mr Smith's block</td>
<td>0.550</td>
<td>Reset the road with a good skid resistant material</td>
<td>0.15 km</td>
<td>3.12</td>
<td>$1.000</td>
<td>1992</td>
<td>10 years</td>
<td>0.72</td>
<td>Action Complete</td>
</tr>
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<td>1992</td>
<td>10 years</td>
<td>0.72</td>
<td>Action Complete</td>
</tr>
</tbody>
</table>
Budget scenario analysis

<table>
<thead>
<tr>
<th>Study area</th>
<th>Hazard</th>
<th>Treatment</th>
<th>PRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Servell St</td>
<td>Sight Distance Intersection</td>
<td>Cut back vegetation</td>
<td>1.20</td>
</tr>
<tr>
<td>Main North Road Between Penrith and Sevenhill</td>
<td>Line Marking, Edgeline, Tone line</td>
<td>Install high quality edge lines</td>
<td>1.09</td>
</tr>
<tr>
<td>Main North Rd</td>
<td>Clear Zone (roadside objects)</td>
<td>Guardrail</td>
<td>0.58</td>
</tr>
<tr>
<td>Stillwater Street from Lower Risk Road to Keppel Road</td>
<td>Skid Resistance, Guardrail, Midblock</td>
<td>Repave with high skid resistant, 74mm</td>
<td>0.28</td>
</tr>
<tr>
<td>Keppel Street from Lower Risk Road to Keppel Road</td>
<td>Horizontal Alignment (corner radius)</td>
<td>Retain curves and move straight section of road</td>
<td>0.50</td>
</tr>
<tr>
<td>Holmdale - Oldtown Rd</td>
<td>Diverge Zone (roadside objects)</td>
<td>Guardrail</td>
<td>0.19</td>
</tr>
<tr>
<td>Kidd Road from West Coast Highway to Swanbourne Rd</td>
<td>Street Lighting, Midblock</td>
<td>Upgrade lighting to new Australian Standard</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Cement order of projects achieves a risk reduction of $13,856.11 for $22,899 Budget
Appendix F  Example Monitoring Databases

Collection of information on the safety performance of various measures is important to determine how effective these measures are. Monitoring databases are used to meet this need, and typically include information on the type of measure, location, and crashes both before and after treatment. A number of states in Australia maintain such databases, but it is often not possible to draw conclusions about reductions in crash numbers due to the small number of schemes of different types. National crash database systems exist in a number of locations, and given the greater number of potential safety schemes, allow greater scope for detailed analysis. Examples of such databases include the MOLASSES database in the UK and the Crash Reduction monitoring system in New Zealand.

**UK MOLASSES Database**

The UK based MOLASSES (Monitoring Of Local Authority Safety SchemES) system is designed to collect information on road safety engineering schemes and provide that information as required. The database was first implemented in 1991 by the CSS (formerly the County Surveyors Society), and is now managed by TRL Ltd. It was instigated as a way to encourage better monitoring of safety engineering works. Authorities are not compelled to contribute to the database, and only 20% have contributed at some point. However, as of 2000, nearly 2200 schemes were entered into the system with ‘before and after’ data, and a further 2000 schemes with only ‘before’ data.

For a scheme to be included in the system, set information is required including:

- a scheme description
- scheme location
- length of scheme (for routes)
- scheme cost
- ‘before and after’ crashes with dates of monitoring periods (if sufficient time has not passed for ‘after’ monitoring, then reminders are sent when three years worth of after data becomes available.

General results on the benefits of treatment types are available from the MOLASSES website (http://www.trl.co.uk/molasses/index.htm), or requests can be made for more detailed information.

Given that the submission of information on schemes is voluntary, it is possible that the system suffers from a bias towards more successful schemes (although information on both successful and unsuccessful schemes is requested). It is therefore possible that the benefit of the measures assessed will be overly optimistic. In addition, control sites are not included in this database, and so again the benefits of measures will most likely be higher than in reality as factors such as regression to the mean, and general improvements in safety resulting from other measures will not have been accounted for. However, this may be the case for all the measures assessed, so when comparing different treatment types, the database may provide a good relative comparison of treatment effectiveness.

**New Zealand Crash Analysis System**

The New Zealand Crash Reduction Study Program started in 1985, and since 1989 a monitoring system has been used to collect information on its effectiveness. The New Zealand Crash Analysis System (CAS) is used to evaluate the overall effectiveness of the program, as well as the success of treatments or packages of treatments where this is possible.

Information collected includes:

- location
• road features (including road type, speed limit, road classification, and roadside development)
• cost of treatment (including provision for estimated and actual costs)
• treatment used (including provision for multiple treatments)
• date each treatment was implemented
• crash type addressed.

As the monitoring system is an integral part of the crash database system (which is also linked to the asset management system), it is possible to conduct quite complex analyses.

As of November 2005 there were around 5200 crash reduction study locations entered into the system, with 3000 locations entered where all works have been completed. Reports are periodically released on the effectiveness for specific treatment types based on the information within the database (available from: www.landtransport.govt.nz/roads/crash-reduction-programme.html). Given that all schemes completed as part of the Crash Reduction Study Program are included in the database, this could be seen as a relatively unbiased record of different treatment types. In addition, account is taken of underlying crash trends, with each site assigned a comparison group of injury crashes. However, the data is not adjusted for the issue of regression to the mean, so it could be expected that the results overstate the effectiveness of various measures.
Austroads’ Guide to Road Safety Part 7: Road Network Crash Risk Assessment and Management introduces the concepts of risk assessment and risk management in the road safety network context. The joint Australia and New Zealand Standard on risk management (AS/NZS 4360:2004) is used as the basis and structure for this document.

Austroads

Austroads is the association of Australasian road and transport agencies.

www.austroads.com.au