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Austroads

Research Report
AP-R455-14



Model National Guidelines for Setting Speed Limits at High-risk Locations

Model National Guidelines for Setting Speed Limits at High-risk Locations

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Abstract

This report incorporates recent research, best practice examples, and jurisdictional inputs to propose a set of model national speed limit guidelines for setting speed limits at high-risk locations. The model guidelines represent a harm reduction approach to speed limits, an intermediate step towards the Safe System.

The model guidelines are intended to apply to different road categories and functions typical to Australia, while incorporating criteria for reduced speed limits based on severe crash risk, such as:

- road lengths that are narrow, have a substantial level of roadside hazards, have many intersections or property entrances, are curvilinear or undulating, or have higher than average severe casualty crash rates
- higher-risk intersections, especially on high-volume outer-urban arterials, where engineering treatments are not feasible.

The model guidelines aim to provide consistent speed limits on roads and intersections which have a higher severe crash risk, while minimising multiple speed zones over short distances.

Keywords

Speed limit, speed management, crash risk assessment, fatal crashes, serious injury, Safe System.

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About Austrroads

Austrroads' purpose is to:

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

Austrroads membership comprises:

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

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

Acknowledgements

The project team would like to acknowledge the extensive input of the project reference group. This group was made up of representatives from each Australian state road agency, Roads ACT, the NZ Transport Agency, Sunshine Coast Regional Council, and Mornington Peninsula Shire. The in-kind support of the stakeholders through provision of trial data and technical support was most appreciated.

This report has been prepared for Austrroads as part of its work to promote improved Australian and New Zealand transport outcomes by providing expert technical input on road and road transport issues.

Individual road agencies will determine their response to this report following consideration of their legislative or administrative arrangements, available funding, as well as local circumstances and priorities.

Austrroads believes this publication to be correct at the time of printing and does not accept responsibility for any consequences arising from the use of information herein. Readers should rely on their own skill and judgement to apply information to particular issues.

Summary

This report provides model national guidance on implementing reduced speed limits on roads with high risk of severe crashes, which cannot be reasonably treated with cost-effective engineering treatments. The model guidelines propose a speed limit setting process based on harm reduction (an intermediate step towards the Safe System).

The guidelines recognise the mobility role of different road categories and functions, and incorporate the key high severe crash risk factors as criteria for reduced speed limits on road lengths that:

- are narrow
- have substantial levels of roadside hazards
- have frequent intersections and access points
- have curved or undulating alignment
- have a history of high severe crash rates

They also provide criteria for high-speed arterial intersections that:

- have high traffic volumes
- are located in outer metropolitan locations
- have experienced a permanent change in traffic patterns, or
- have a significant severe crash history.

The model guidelines aim to provide consistent speed limits on roads and intersections in response to high severe crash risk, while minimising the frequency of speed zone changes.

The objective of the project was achieved through review of the available research evidence and best practice in Australia, New Zealand and in other road safety leader countries. The model guidelines were developed in close consultation with Australian road agencies.

Application of the model guidelines was trialled on selected routes and intersection approaches to ensure that they can be applied in an easy and efficient manner.

The intent of the model guidelines is to inform future revisions of relevant Austroads Guides on speed limits.

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1. Introduction

Safety of roads across Australia and New Zealand varies considerably, and some roads are not of an appropriate standard for their current speed limit. This results in inconsistent levels of crash risk, and hence, increased frequency of fatalities and serious injuries on some roads. Identifying and applying suitable speed limits on such roads is a necessary measure to improve their safety performance. Alternatively, for higher volume routes, infrastructure safety investment is needed to maintain higher speeds in line with the expected mobility function.

This project used recent research, best practice examples, and jurisdictional inputs to propose a set of model national speed limit guidelines for setting speed limits at high-risk locations (Section 8). The model guidelines represent a harm reduction approach to speed limits, i.e. an achievable step towards the Safe System vision.

1.1 Background

'Safe speed' is one of the cornerstone areas of intervention for Australia's *National Road Safety Strategy 2011–20* (Australian Transport Council 2011). The Strategy aims to achieve speed limit setting practices, which are a step towards the Safe System. Such speed limits would be better aligned with the inherent risk of severe crashes, the road and roadside environment. Similar aims are expressed by *Safer Journeys: New Zealand's Road Safety Strategy 2010–20* (Ministry of Transport NZ 2010).

The project extended the crash risk-based approach for setting speed limits, which has been the current practice since the late 1980s. The project builds upon the recent research carried out by Austroads under project ST1433 in 2009–10 (Austroads 2010a), which established nationally agreed principles for setting speed limits in the Safe System context (harm minimisation). The harm reduction approach, which was also identified in Austroads (2010a), forms the basis for the current project.

1.2 Objectives

This project objective was to develop model national guidelines, which directly supports the priority actions under the Strategy (Australian Transport Council 2011), which are to:

11. Review speed limits where risk levels were high and engineering solutions were not feasible or cost-effective:
 - a. Set safe speed limits on road lengths that were narrow, have substantial levels of roadside hazards, have many intersections or property entrances, were winding or undulating, or have higher than average serious casualty crash rates.
 - b. Reduce speed limits at high-risk intersections, especially on high volume outer urban arterials.
12. Develop new risk-based national speed limit guidelines for different road categories/functions. Guidelines should encourage consistent limits based on measured risk/crash rates, while minimising multiple speed zones over short distances.

The outputs of this project, together with the concurrent project ST1762 on harmonisation of speed limits, will provide inputs into future revisions of Austroads Guides on speed limit setting (Austroads 2008a, 2008b) and of the Australian Standards for speed control (Standards Australia 2008).

The model guidelines are not expected to deal with the full breadth and detail of speed zoning practice, e.g. issues relating to signing, the authorisation process and process documentation. References to existing Austroads Guides and standards have been made on these matters for completeness.

1.3 Scope

This report documents development of the model guidelines in 2011–12 and 2012–13. The following tasks were completed in 2011–12:

- Undertaking of an Australian and international literature and practice review on crash risk associated with speed and road infrastructure, accounting for crash risk in speed limit setting, implementation of reduced speed limits on higher-risk roads and intersections and road lengths not amenable to cost-effective engineering treatments.
- Development of draft model guidelines on the basis of the literature review and inputs by the reference group.
- In consultation with jurisdictions, the selection of up to six higher-risk routes/intersections for the application of the draft model guidelines.
- Identification of data and its collection to undertake assessment of higher-risk severe crash locations, and to recommend a speed limit using the draft model guidelines.
- Development of a brief dissemination plan to facilitate the swift and comprehensive adoption and application of the model guidelines, as part of the revision of the current Austroads Guides that deal with speed limit practices (Austroads 2008a, 2008b).
- Preparation of an interim report.

The following research tasks were carried out in 2012–13:

- Trial application of the draft model guidelines based on the data received from jurisdictions (13 locations). It was agreed by the reference group that this was to be a hypothetical application of the guidelines, which did not involve actual speed limit changes.
- Convening of a reference group workshop to discuss the findings and seek further input into the model guidelines.
- Review of the draft model guidelines based on the conclusions from the trial application and on reference group feedback. Refinement and finalisation of the model guidelines by mid-2013.
- Submission to Standards Australia proposing amendments for its consideration to AS 1742.4: Speed Controls (2008) to recognise the risk-based methodology for setting speed limits at higher-risk locations.
- A dissemination plan and identification of potential amendments to the Austroads Guides.
- Development of the research report drawing together the key findings from this project, including the finalised model guidelines for consideration as part of the future review of the Austroads Guides dealing with speed limits and speed management.

2. Methodology

The project comprised the following main tasks:

- literature reviews of research evidence and best practice in risk-based speed limit setting
- consultation with the reference group and key stakeholders
- development of draft model guidelines for high crash-risk locations and consultation
- trial application of the draft model guidelines
- refinement and finalisation of the model guidelines following consultation
- development of a dissemination plan and amendments for consideration with relevant Austroads Guides.

2.1 Literature Review

The objective of the first task in the project was to review available literature on the implementation of reduced speed limits on higher-risk roads, intersections and road lengths. The review also referenced recent Austroads and road agency research relating to recognition of crash risk in the setting of speed limits.

The literature review covered the following subjects:

- setting speed limits in the Safe System context, including the role of a risk-based approach
- identification of road section and intersection characteristics contributing to high crash risk
- examples of higher-risk locations not amenable to road infrastructure improvements
- speed limit guidelines used on different types of higher-risk roads
- examples and trials of lower speed limits at higher-risk locations; and the effectiveness of these trials in reducing mean speeds and casualty crashes.

The literature review was designed to inform further discussions among the reference group on the development of risk-based guidelines for setting speed limits, i.e. the second project task.

In order to identify relevant research, a literature review was conducted using the resources of ARRB Group's MG Lay Library, the leading land transport library in Australia.

These resources included the library's own comprehensive collection of technical land transport literature and information retrieval specialists with extensive experience in the transport field, as well as access to the collections and expertise of other transport-related libraries throughout Australia and internationally.

Used in this literature search were the Australian Transport Index (ATRI) and Transportation Research Information Documentation (TRID) databases, whose content is coordinated by ARRB Group and the OECD/US Transportation Research Board, respectively. Use of these databases ensured wide coverage for quality research material within the subject area, from both national and international sources.

In addition, the authors contacted international road safety practitioners and speed management experts to seek direct input on overseas practice.

2.2 Consultation and Development of the Guidelines

The preliminary draft of the model guidelines was based on the literature review and data analysis. The guidelines were refined and finalised through the trial application and consultation with the reference group.

The reference group consisted of senior road safety practitioners from the Commonwealth Department of Infrastructure and Regional Development, state road agencies, the New Zealand Transport Agency and local governments. The project reference group met in 2011 and 2012 to discuss the research evidence, best practice, and draft model guidelines, and to agree on the project outputs.

Comments from the Austroads Road Safety Task Force were also received and considered in the finalisation of the model guidelines.

2.3 Trial and Refinement of the Draft Guidelines

The trial of the draft model guidelines produced after the first stage of the project (2011–12) was carried out by applying the guidelines to 10 road sections and three intersections selected from the nominations provided by the reference group. The locations used in the trial were in three states: Queensland, Victoria and Western Australia. The group members also provided or agreed to use necessary information enabling evaluation of the risk at the locations and selection of a recommended 'harm reduction' speed limit.

Hypothetical speed limit reviews were carried out at all 13 locations. Site visits were then conducted at the selected locations to test the guidelines in-field. The documented reviews, along with the commentary were reported back to the reference group during the 2012 workshop. Various issues with applicability of the guidelines were discussed and resolved. Feedback from the reference group was used to refine the model guidelines to the version presented in this report.

2.4 Dissemination Plan

A dissemination plan was prepared for further consideration. The aim of the plan was to inform practitioners, in the form of model guidelines, of factors that may be considered in the application of speed setting guidelines at locations that have relatively high levels of crash risk. In the context of the guidelines being a model of speed zoning practice, and other concurrent Austroads projects on speed limits (NT1796, ST1762), this dissemination plan may be considered in future harmonisation of speed zoning guidelines across Australia.

2.5 Identification of Potential Amendments to Austroads Guides

This task involved analysis of the final draft of the model guidelines in the context of the existing *Guide to Road Safety – Part 3: Speed Limits and Speed Management* (Austroads 2008a) and *Guide to Traffic Management – Part 5: Road Management* (Austroads 2008b, Section 5). The review identified guidance changes that could be considered as a result of the model guidelines.

3. Review of Safe System and Risk-based Speed Limits

The following sections provide a review of the literature relating to the inter-related issues of speed, speed limits, crash likelihood and severity, road users and road infrastructure. The review of these issues was carried out to inform reference group discussions leading to the development of the model guidelines in Section 8. In particular, the review set up the context of harm reduction, a step towards the Safe System, as the key approach to determining speed limits at higher-risk locations.

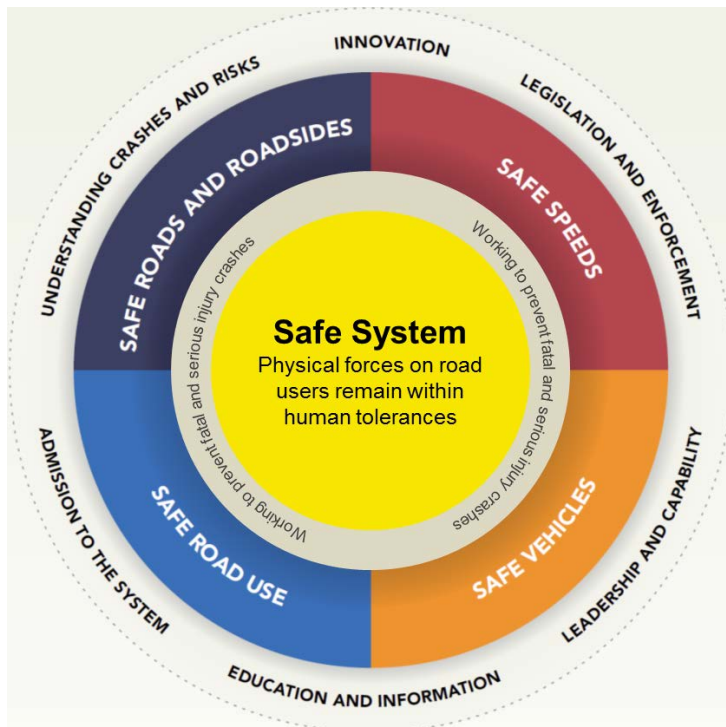
3.1 Safe System Speeds

Australia adopted the Safe Systems approach to road safety more than a decade ago (Australian Transport Council 2011). The Safe System approach aspires to create a road system in which human error does not result in death or serious injury. The approach accepts that humans will make errors, so crashes will continue to occur. In addition, humans are physically vulnerable and are only able to absorb limited kinetic energy during a crash before serious injury or death occurs.

The idealised Safe System takes account of human errors and physical tolerances so that road users are able to avoid serious injury or death in the event of a crash. The Safe System aims to manage vehicles, the road and roadside infrastructure, as well as speeds to minimise death and serious injury as a consequence of a road crash.

A Safe System is composed of four essential and interlinked pillars, which form the areas of strategic focus and ongoing improvement. Figure 3.1 presents these using the New Zealand example of a Safe System diagram.

Figure 3.1: Components of the Safe System approach



Source: Based on Ministry of Transport NZ (2010).

Within this context, Austroads (2005) summarised the biomechanical tolerances of humans for different crash types. Table 3.1 presents the maximum survivable impact speeds for various crash types. These human tolerances need to be considered in the management of speed to ensure that in the event of a crash, no road users are killed or seriously injured.

Table 3.1: Biomechanical tolerances to impact¹, or Safe System speeds

Crash type	Impact speed
Car/pedestrian/cyclist	20–30 km/h
Car/motorcyclist	20–30 km/h
Car/tree or pole	30–40 km/h
Car/car (side impact)	50 km/h
Car/car (head-on)	70 km/h

Source: Austroads (2005).

Table 3.1 shows that pedestrians, cyclists and motorcyclists are the most vulnerable road users in the current speed limits regime which generally starts at 40 km/h.

The figures used by Austroads (2005) were challenged by the findings of several later studies (Richards 2010; Rosen & Sander 2009). These studies found that survivable speeds may be higher by up to 10 km/h than previously published (Austroads 2005). Even so, it is considered that serious injuries would occur at lower speeds. Thus, the figures indicated by Austroads (2005) are still an indicative guide of human tolerance in relation to fatal and serious injury outcomes for different crash and road user scenarios.

Austroads (2010a) reviewed a number of published evaluations of speed limit reductions. The associated crash reductions indicated that vulnerable road users (i.e. pedestrians, cyclists and motorcyclists) were the greatest beneficiaries of speed limit reduction in urban areas. It is of note that pedestrian casualty crashes halved as a result of the blanket speed limit reductions from 60 km/h to 50 km/h on local streets (ARRB Transport Research 2000).

3.2 Speed and Crash Risk

A direct causal relationship between speed and crash risk was established by Nilsson (1984), and has been reviewed a number of times since. Elvik, Christensen and Amundsen (2004) reaffirmed the relationship between speed and road safety based on a number of arguments, including:

- The consistency of the statistical relationship between speed change and road safety performance change. When speed is reduced, the number of crashes and injuries falls in 95% of the cases. When speed is increased, the number of crashes and injuries increases in 71% of the cases.
- Most of the evidence came from before-and-after studies where statistical analysis confirmed that reductions in crashes occurred as a result of reductions in speeds.

There is further empirical evidence for the causal link between increases in speed and a subsequent increase in risk from a study by Sliogeris (1992). In the late 1980s, the speed limit for rural and outer-metropolitan freeways in Victoria, Australia was increased from 100 km/h to 110 km/h, but was then reduced again to 100 km/h due to safety concerns. This offered an opportunity to study the safety effect of increases in speed limits for these types of roads. A 'before', 'during' and 'after' study was conducted on these roads spanning a 2½ year period.

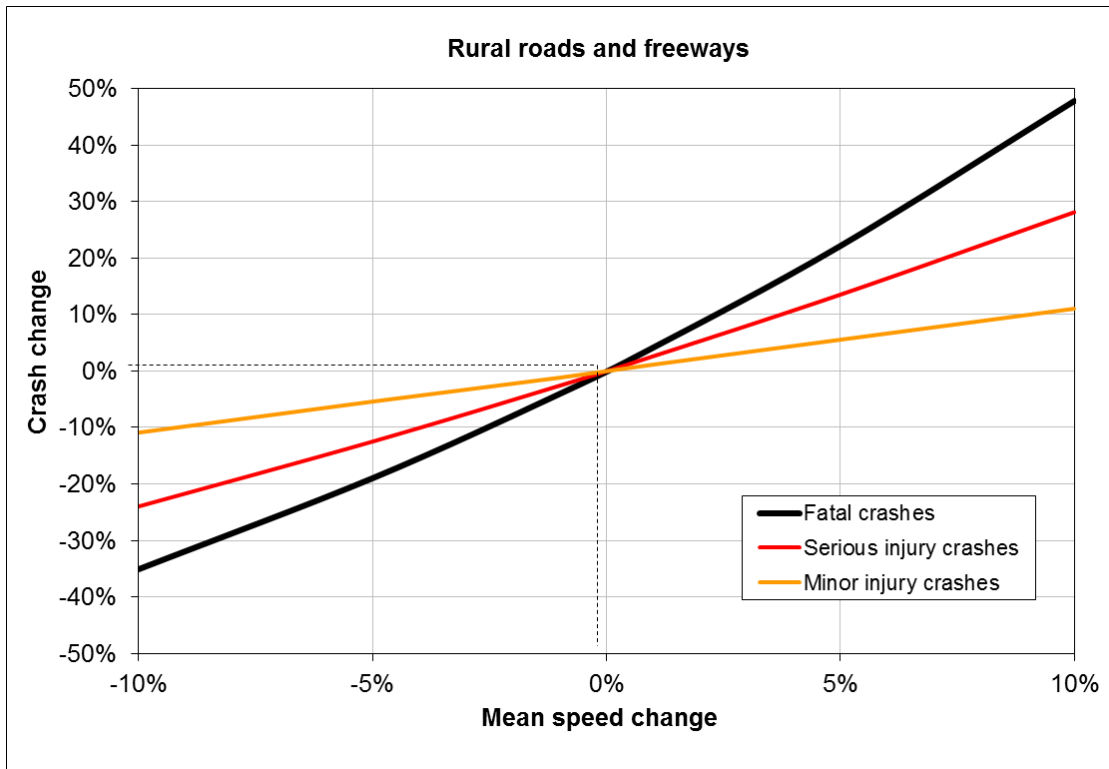
When the speed limit was increased to 110 km/h, the casualty crash rate increased by almost 25%, and when the speed limit was decreased back to 100 km/h, the rate decreased by about 20%. In both cases, the changes were statistically significant.

¹ The chance of a fatal outcome is less than 10% at these speeds, and increases sharply above them.

Elvik, Christensen and Amundsen (2004) analysed almost 100 separate speed studies covering 20 countries. The study included 460 estimates of a change in the casualty rate in response to a change in mean speed. A meta-analysis was conducted on this combined data, and the results provide strong support for the Power Model² developed by Nilsson (1984). This shows that even small reductions in mean speed can result in substantial decreases in fatal and injury crashes.

Elvik led several further studies reviewing the relationship between mean speed change and safety outcomes. In 2009, he updated his 2004 meta-analysis by including results from 115 studies, which contained 526 estimates of speed change and its safety implications (Elvik 2009). This review confirmed the relationships shown in Figure 3.2 and Figure 3.3.

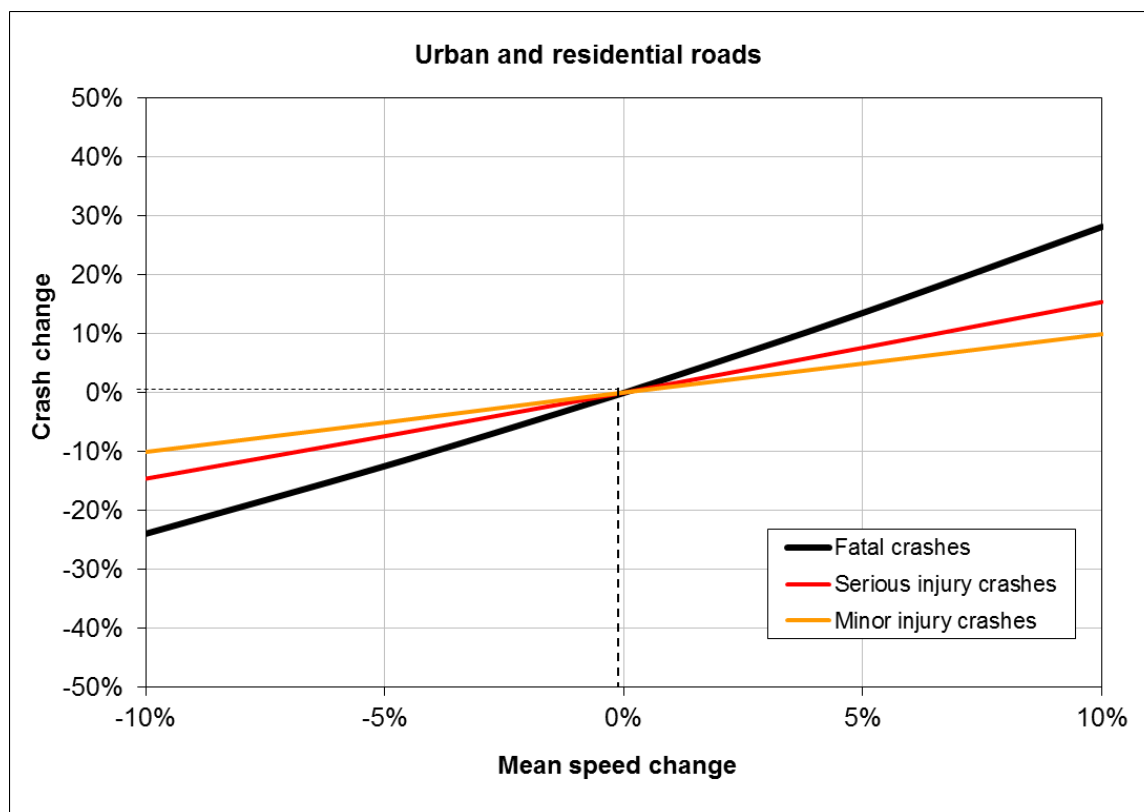
Figure 3.2: Mean speed changes versus expected crash changes for rural roads and freeways



Source: Based on Elvik (2009).

² Nilsson's Power Model: % change in crashes = 100 - 100 x (mean speed after / mean speed before)ⁿ, where n is the empirically derived power exponent, which is different for different crash severities and road types.

Figure 3.3: Mean speed changes versus expected crash changes for urban and residential roads



Source: Based on Elvik (2009).

The 2009 review also defined the differences in the Power Model exponents between the generally higher and lower speed limit roads (this was already evident in Elvik, Christensen & Amundsen 2004). It can be seen from Figure 3.2 and Figure 3.3 that the gains in safety due to similar mean speed reduction were lower on urban roads than on high-speed rural roads.

The 2009 revision of the Power Model indicates that the expected crash savings from mean speed reductions would be slightly lower on rural roads and freeways than previously estimated by Elvik, Christensen and Amundsen (2004). The savings on urban roads would be substantially lower than estimated with models pre-dating 2004. This was confirmed recently by further work by Cameron and Elvik (2010).

One additional finding of interest from Elvik's 2009 review was that the Power Model exponent (particularly for fatal crashes) has been reducing over time. This means that the effect on safety from a change in speed has become smaller. Elvik speculates that this is most likely due to improved safety devices (vehicles and road infrastructure), and that crashes that were not survivable 40 years ago are now survivable more often.

Elvik (2013) provides the latest findings in the continued refinement of speed-safety models. The data sets used in the 2009 revision were re-analysed by Elvik with the aim of reviewing the fundamental relationship between mean speed change and safety outcomes. Elvik (2013) proposes that an exponential model, not a Power Model, is the preferred mathematical form for estimation of the safety effect. In doing so, a new model form and parameters are proposed for estimation of fatal, all-injury and property damage only (PDO) crashes, but not for serious injury crashes. Elvik (2013) recognises that the serious injury crash data pool was not sufficient to develop a robust model.

Importantly, the new findings recognise that a change in safety depends on the initial mean speed, not just mean speed change. Higher benefits can be estimated for mean speed reductions from higher initial speeds. This is an improvement from the 2009 findings by Elvik, which recognised only high- and low-speed roads as shown in Figure 3.2 and Figure 3.3.

Unfortunately, Elvik (2013) provides little in the way of practical interpretation of the findings. For example there is no discussion about differences in crash change estimates resulting from use of the new exponential model and the 2009 Power Model. The new model produces notably greater fatal and injury crash reduction estimates than the 2009 Power Model applied for the same mean speed changes. The lack of serious injury exponential model makes it difficult to apply the new findings in the Safe System policy context.

It is proposed to monitor how further publications on this subject discuss and address the above points. In the meantime, it is proposed to rely on the more conservative Elvik (2009) Power Model for safety estimates from mean speed change.

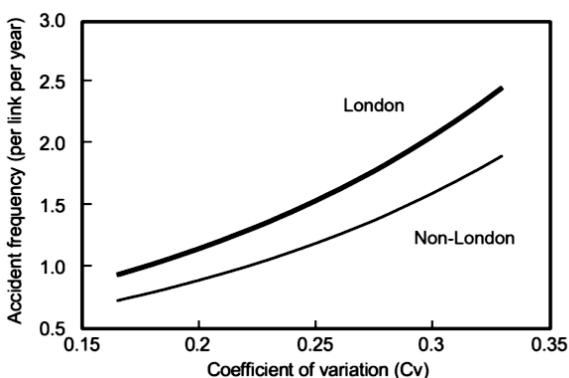
3.3 Speed Variation and Crash Risk

UK research on the relationship between speed and safety outcomes generally confirmed the findings of Elvik’s research. The study by Taylor, Lynam and Baruya (2000) involved a cross-sectional analysis of the mean speeds of multiple urban road midblock sections (off-peak, free flow conditions) and casualty crashes. Additionally, the authors included the coefficient of variation of speed, or Cv (standard deviation divided by the mean speed). A large Cv value indicates a significant proportion of vehicles travelling above and/or below the mean speed. A road section with a high percentage of speeding drivers, or drivers making turns and stops would result in a large Cv of speed.

Taylor, Lynam and Baruya (2000) used a generalised-linear statistical modelling technique (GLM) to derive equations for crash frequency per unit link per year, based on mean speed and coefficient of variation. The relationship and both variables were statistically significant.

Based on a large data sample across several urban classified road stereotypes, the authors concluded that casualty crash frequency per link³ per year increased exponentially as the coefficient of variation of speed increased, providing the mean speed remained constant, as shown in Figure 3.4. This means that road safety outcomes were found to be sensitive to speed variation.

Figure 3.4: The effect of speed variation on casualty crashes

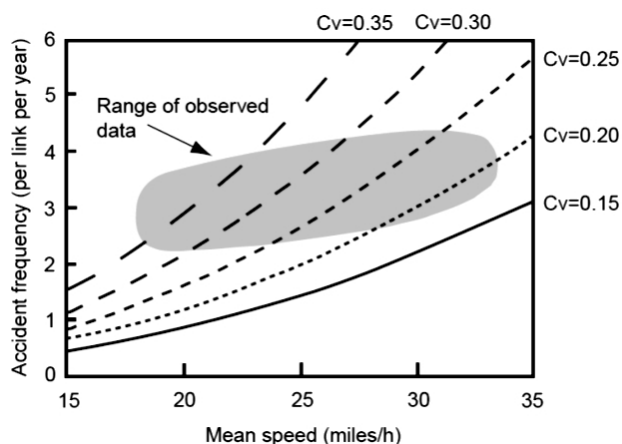


Source: Taylor, Lynam and Baruya (2000).

³ A standard midblock length used in the study.

The authors noted that mean speed and Cv were highly correlated according to road type. Based on the project data, Taylor, Lynam and Baruya (2000) proposed a broader relationship between casualty crash frequency, mean speed and coefficient of variation, all other things being equal. Figure 3.5 shows this relationship. It indicates that doubling of the Cv from 0.15 to 0.30 at 30 miles/h (approx. 50 km/h) would more than double the casualty crash risk.

Figure 3.5: Proposed relationship between casualty crashes, mean speed and speed variation



Source: Taylor, Lynam and Baruya (2000).

Taylor, Lynam and Baruya (2000) noted that the findings confirmed earlier US findings by Garber and Gadirau (1988) who found that speed variability was an important predictor of crashes on rural highways.

The authors pointed out that mean speed and speed variation were highly correlated, with Cv generally being lower at higher mean speeds. This was observed to be related to road categories and functions, i.e. lower mean speeds and higher Cv were observed on congested city roads, and higher speeds and lower Cv on fast flowing outer-suburban arterials. Thus, speed variation should be seen as a symptom of the operational conditions for a given road, rather than an operational variable that can be easily manipulated. Some of the common situations leading to increased speed variance on urban roads include:

- roadside parking, drop-off and pick-up activities
- frequent intersections, access points and median breaks without adequate auxiliary lanes
- roadworks and frequent speed limit changes
- frequently crossing pedestrians and crossing facilities
- public transport facilities sharing road space with through traffic
- geometric constraints such as bends, crests and road narrowing
- congestion.

The significance of the Taylor, Lynam and Baruya (2000) findings rests in careful recognition of speed variation and mean speed in setting of speed limits on urban roads. The practical meaning of the relationship in Figure 3.5 is that urban speed limits could be used to reduce mean speeds (as has been the practice). Speed limits should not be set so low as to be ignored and to cause increased speed variation⁴. Also, speed limits can be used to reduce existing speed variation by being matched closer to the mean speed, without necessarily changing it. In both cases, the speed limits rely on public acceptance and enforcement. Careful application of speed management techniques can have a similar effect on both mean speeds and speed variation.

⁴ This may not occur under a strict enforcement regime such as point-to-point.

Taylor, Baruya and Kennedy (2002) carried out a similar study for several categories of undivided rural roads in the UK. For this road environment, it was found that Cv was weakly correlated with mean speed, and Cv had no strong relationship with casualty crash risk. The conclusion reached by the authors was that speed variability did not influence crashes in the study sample.

The difference in findings relating to speed variation on urban and rural roads reflects the different characteristics of the speed distributions in these road environments. It is thus concluded that speed variation is likely to play a more significant role in speed limits and speed management on urban roads.

There would be a benefit in carrying out further research in this area in order to update and better understand the relationship between speed variation and safety outcomes.

3.4 Harm Minimisation – The Safe System Approach

The established approach to speed limit setting was based on a broad range of factors. These factors include road function, abutting level of development (built-up, farmland), various road engineering features, crash history, operating speed, and sources of traffic flow interruption (Austroads 2010a). Austroads (2008a) reinforced the importance of taking into account crash history as a factor when setting speed limits.

In this context, the Austroads (2010a) investigation of speed limits and safety relationships produced a set of four new principles for setting speed limits based on the Safe System principle of harm minimisation⁵. These principles included both the likelihood and severity of crashes in the consideration of speed limits. A broader range of road features was proposed for consideration than under the existing approach. Under the principles in Austroads (2010a), the aim of speed limit setting became minimisation of death and serious injury due to road environment factors, including speed.

The proposed principles involve a process of consideration of safety and mobility, and the practical reconciliation of any gaps between them to arrive at a set of speed limit options. The principles proposed by Austroads (2010a) are as follows:

- | | |
|--------------------|---|
| Mobility: | What speed limits does the community expect for each road class and function? For example, undivided urban arterials are typically 60 km/h. |
| Harm minimisation: | What are the safe speed limits for a given road given the existing conditions? Safe speed limits are defined by the biomechanical tolerance to crash impact forces as presented in Table 3.1, e.g. 30 km/h for roads where vulnerable road users are exposed to vehicular traffic. |
| Gap analysis: | Evaluation of the existing level of protection offered by the road to identify gaps between the speed limit and road features leading to the potential for fatal and serious injuries. A preliminary checklist of primary and supporting Safe System solutions was developed to match the speed limit to existing road features, or to propose road infrastructure improvements, so that harm minimisation could be achieved. |
| Driver perception: | Management of the road environment and traffic speeds, if necessary. In some cases, further infrastructure changes would be desirable to lower actual speeds to support a lower speed limit. |

⁵ That is, avoidance of death and serious injury due to road environment factors. This version of Vision Zero depends on the integration of the benefits of Safer Roads and Safer Speeds with Safer Vehicles and Safer Road Users. This includes minimising harm through providing a road environment forgiving of human error. Grave harm may still occur if one of the key elements fails, e.g. road users choose not to comply with safer speed limits.

Consideration of each principle is a separate step in an iterative process. The result is one or more speed limit options, some of which may require changes to the infrastructure to provide safe travel at a recommended speed limit. Jurewicz and Thompson (2010) presented this process in more detail using an example of a suburban undivided arterial road with infrequent pedestrian movements. They suggested that at the existing 60 km/h speed limit, the transition towards Safe System conditions would require use of roundabouts at intersections, control of movements at minor access points, and provision of wide cycle lanes to increase the offset to roadside hazards.

3.5 Harm Reduction – A Step Towards the Safe System

Consensus as to which road infrastructure features would be required to provide safe travel in the Safe System framework is still a subject of ongoing debate among experienced road safety practitioners. Even if this fundamental issue is resolved in the immediate future, provision of Safe System infrastructure would be delivered over many years.

Austrroads (2010a) recognised that public acceptance of very low speed limits compensating for the absence of Safe System road features would be limited to road environments involving vulnerable road users, e.g. shopping strips, school zones, shared zones.

Thus, in the short- to mid-term⁶, a harm reduction approach to speed limits could be implemented while road agencies gradually move towards defining and implementing Safe System infrastructure. A crash-risk-based assessment process could evaluate road sections for risk of severe crash outcomes. Where the risk is high, and where road improvements cannot be justified, speed limits could be adjusted down as a harm reduction measure. This approach forms the basis of setting speed limits at higher-risk locations.

3.5.1 Existing Risk-based Approaches to Speed Limit Setting

Jurewicz and Turner (2011) presented a number of possible approaches to the crash-risk-based approach to speed limit setting. Each is described in the following sub-sections:

- existing
- specific road user issues
- crash history
- crash risk assessment.

The options for combining these approaches in the new risk-based guidelines are discussed in Section 3.5.2.

Existing

Jurewicz and Turner (2011) noted that Austrroads (2008a) guidance on the approach to speed limit setting took into account such risk factors as:

- crash rates per kilometre of travel (100 million VKT)
- road function
- road engineering characteristics (e.g. presence of median, turning lanes, pavement width, etc.)
- intensity of abutting development (e.g. built-up, partially built-up, rural, etc.)
- speeds (not the 85th percentile)
- presence of vulnerable road users, traffic patterns.

⁶ Austrroads (2010a) proposed that in the long-term, Safe System-based road planning and design guidelines would be developed to gradually implement agreed Safe System road features that do not kill or maim road users. This may be aided by passive and active vehicle safety technology (e.g. lane departure warning/control).

Through methodical consideration of these factors, crash risk was included in the selection of speed limits. Lower speed limits were recommended for road sections with relatively high crash-risk features. Often the lower speed limit was accompanied by supportive infrastructure where appropriate. There are a number of examples of guidelines and standards that draw on this approach while retaining some earlier practices, or placing more emphasis on some factors than others. These include Main Roads WA (2012), Standards Australia (2008) and VicRoads (2010). Some were developed into online decision support tools to provide consistent speed limit setting practice (e.g. VLimits 2.0, SLR-QLIMITS 3.0, WALIMITS 3.0, and others).

Specific road user issues

Jurewicz and Turner (2011) noted that speed limits were lowered to address unacceptably high risk levels for selected road user groups (e.g. pedestrians, cyclists, heavy vehicles). Sometimes, the speed limit reductions were ad hoc departures from the guidelines to address broad risk conditions not covered by the guidelines (e.g. on high-risk motorcyclist routes). In many cases, however, the existing guidelines provided criteria-based speed zoning guidance for high-pedestrian-activity commercial areas, shared zones, or time-based school zones.

Crash history

Most jurisdictional speed zoning guidelines reviewed by Jurewicz and Turner (2011) took crash rates per kilometre of travel into account when reviewing speed limits, although it was rarely the leading factor in recommending a speed limit. Typically, speed limit reductions due to crash history were approved after consultation with the road safety department in the head office, on a case-by-case basis. Other factors were usually taken into consideration, such as vulnerable road users and road alignment.

Jurewicz and Turner (2011) considered a hypothetical speed limit setting system that focussed predominantly on crash history. A process similar to black length analysis was considered to identify road sections with a history of severe injury crashes, with a view to reduction of speed limits. Trigger levels for reduced speed limits were set for roads of different class and function (e.g. number of severe crashes per km in five years).

Since 'high crash' black lengths typically form isolated road sections from several hundred metres to several kilometres in length, this approach would potentially target only a small proportion of the road network, resulting in short, isolated sections of lower speed limits. A high level of communication with road users was thought to be required to explain the reason for localised speed limit reductions. Also, such an approach could in some instances necessitate complementary infrastructure works to constrain speeds, as well as additional enforcement of the speed limit.

Jurewicz and Turner (2011) noted that such an approach could become an economically attractive but questionable, alternative to addressing localised road safety problems in lieu of proven engineering treatments. Lowering of the speed limits based on crash record only could mask infrastructure deficiencies, and potentially create a further safety problem with the possibility of increasing vehicle speed variation.

Jurewicz and Turner (2011) listed several additional reasons why the use of crash history alone may not be sufficient to identify higher-risk sites. There is a relatively low reporting rate for casualty crashes in rural areas. Although it is expected that all fatal crashes are recorded, it is believed that a large proportion of the serious and minor injury type crashes are not. Information from overseas indicates that only around 60% of serious crashes were reported, with a significantly lower percentage for minor injury crashes (Alsop & Langley 2001, Ward, Lyons & Thoreau 2006). Australian-based research has also identified under-reporting of injury crashes (Cercarelli 1998; Roy Morgan Research 1994). The reporting rate is likely to be even lower in rural areas.

In addition, in rural areas, crashes are often dispersed, including those involving vehicles running off the road. Analysis by ARRB using Victorian and New Zealand crash data showed that only a third of fatal crashes occurred in locations classed as black spots (Roper & Turner 2008). In addition, investigation of New Zealand crash data revealed that more than half of the fatal crashes occurred at locations that had no recorded crashes in the previous five years.

As a result, a large proportion of high-crash-risk roads that did not record crashes would never be considered for a lower speed limit and would retain high speed limits under a crash-history-only approach.

Crash risk assessment

There have been few examples of crash risk assessment used in speed limit setting to date (e.g. KiwiRAP as noted by New Zealand Transport Agency 2011). A risk assessment approach has been used mainly for identification of candidate sites for further investigation, road safety improvements, road safety program development, and building public awareness of road safety issues (Austroads 2013a). A risk score or level is more closely correlated to crash rate per kilometre of travel, rather than to frequency of crashes per kilometre of road. It is thus limited to estimating the individual crash risk, rather than the collective crash risk.

Typically, risk assessment does not include crash history in the calculation of the risk score. The measure of risk of future crashes is based on the relative safety of various road environment elements such as: curvature, road width, grade, roadside hazards, access/intersection frequency, speed, and presence of vulnerable users. There are several examples of risk assessment approaches that also account for traffic volume⁷ (i.e. exposure to risk). Increasing traffic volume can be used as a relative risk factor or as a continuous mathematical risk function.

Estimated operating speeds or existing speed limits have also been used as a risk assessment factor. They have been used as indicators of higher risk where the traffic speed was not compatible with the road geometry and abutting development, and of the relative crash severity.

To date, crash risk methodologies have been mainly based on all-casualty crash risk factors rather than on severe crashes. The emerging research on crash risk factors is being refocussed on fatal and serious injury crashes (Austroads 2013a, Jurewicz & Zivanovic 2011). This will inform the next generation of risk assessment tools based on severe crash risk and measurement of Safe System performance.

Many of the crash risk factors noted in this section were already in use in speed limit setting. Crash risk levels based on road features and some operational factors may be derived according to a number of methodologies, as outlined in Section 4.1.

One of the limitations of using a risk assessment approach to setting speed limits could be reliance on large amounts of road environment data (New Zealand Transport Agency 2011).

3.5.2 Option for the Model Guidelines

At many locations, road features incompatible with a road's function, operation and users are not the only risk factors in the frequency of severe crashes. Roads with high traffic volumes and low-risk features can still accrue high crash numbers over time (e.g. freeways). Thus, as an optimal way of identifying higher-risk roads for the purpose of speed limit setting, Jurewicz and Turner (2011) suggest combining the three approaches discussed in the previous sections:

- crash rates per kilometre of travel
- road use and road user risk factors
- engineering risk assessment.

⁷ For example: Road Safety Risk Manager (RSRM), Urban Crash Risk Assessment Tool (UCRAT), or the emerging Austroads National Risk Assessment Model (ANRAM).

Additionally, speeds not compatible with the road environment and its use should also be considered in the process (discussed in Sections 3.2 and 3.3).

Combining these approaches in the model risk-based guidelines would promote self-explaining roads, i.e. those roads not designed for their actual function and operation (hence higher-risk) would consistently attract lower speed limits. The majority of roads would be expected to remain at their existing speed limits, with the exception of the higher-risk sections where the gap between the intended and actual functions and operation cannot be bridged with infrastructure improvements.

Indicators of crash risk have been present in the speed limit setting approach since the late 1980s. Thus, it would be reasonable to evolve this approach in the Safe System context, i.e. towards eradication of fatal and serious injury crashes. A revised risk-based approach to speed limit setting would need to account for both crash likelihood and crash severity. A focus on the likelihood of severe crashes (fatal and serious injury) would achieve this aim. Thus, the guidance for speed limit selection based on the objectives of this project should include:

1. the base-line speed limits for roads of different function and category
2. situations that constitute a sufficient increase in severe crash risk to trigger consideration of a lower speed limit, e.g.:
 - (a) high severe crash rates per kilometre of travel
 - (b) specific road use and user issues
 - (c) recognised high-risk road engineering features
 - (d) speeds not suited for the road environment
3. the suggested reduced speed limits when any of the nominated high-risk factors are present.

A lower speed limit could be considered where any given factor would raise the risk of severe crashes by ≥ 2 times above the average. The severe crash risk factors based on the findings of this project are summarised in Section 4.2 and Appendix A. They include such features as lack of shoulders, narrow clear zones, high frequency of curves, high numbers of vulnerable road users, and frequent intersections.

Time- or activity-based factors should be considered in the selection of special-purpose speed zones such as school zones, variable speed limits, heavy vehicle speed limits, and strip shopping zones.

4. Review of Crash Risk Assessment

This section provides an overview of the crash risk assessment methods. Secondly, it provides a summary of crash risk factors based on an overview of recent literature and crash rates analysis. The majority of the provided factors relate to severe crashes. Further, it presents a number of typical examples of higher-risk locations where lower speed limits could be appropriately considered, based on the available literature. This information is intended to support formulation of the technical parameters of the model risk-based speed limit guidelines.

4.1 Methods of Crash Risk Assessment

Experience in the review and development of risk-based decision support systems, strengthened by the recent New Zealand experience (New Zealand Transport Agency 2011), suggests several key criteria to be considered in selecting a decision support system. Ideally, a risk-based decision support system would have the following criteria:

1. The system draws on relevant local research and experience as much as possible.
2. It uses the smallest number of variables required for a robust risk estimate.
3. Data inputs are either easy to collect or already available.
4. The system is transparent and easy to use.
5. It delivers logical and consistent results across a range of environments.

There are several existing risk assessment models available in Australia, New Zealand and beyond (Jurewicz & Turner 2011). They include:

- NetRisk – produces a crash risk score based on several road features and the speed environment. It incorporates speed as one of the variables that affect the risk score, so it is possible to view the impact of a lower speed limit on the risk level. NetRisk comes as an Excel tool developed for Australian conditions. It has been a proven risk assessment tool on rural roads in Queensland.
- Highway Safety Manual (USA) – uses a hybrid crash prediction and risk assessment method to estimate the expected number of crashes for a given road segment. It uses risk factors for operating speed based on the out-dated Nilsson's Power Model (AASHTO 2010). It is based mainly on US research and would need calibration to Australian conditions. The Interactive Highway Safety Design Model (IHSDM) is the associated software that performs many of the calculations of the Manual. Expert knowledge of the approach is required to understand and apply it to road assessment.
- iRAP – expresses the fatal and serious injury crash risk as a Star Rating Score (SRS). The SRS is based on the risk associated with a combination of different road features and selected operational factors. The iRAP v3 version requires 72 input variables for each 100 m road segment. This requires a dedicated road network survey and data coding. iRAP provides a free online tool to process the coded data and recommend risk reduction programs. The operating speeds and speed limits are used as a broad measure of the speed environment within the algorithm. iRAP accommodates speed limit changes as a potential treatment and thus provides a visible change in risk rating as a result of speed management initiatives (International Road Assessment Programme 2009). iRAP requires dedicated resources to assess risk on a mass scale. Its approach focusses on international application and global comparison of crash risk.
- AusRAP – is the Australian version of iRAP.
- KiwiRAP – similar to iRAP but based on a different software platform. It utilises local crash prediction modelling to refine the model in order to improve the correlation between the model predictions and the observed crash performance in New Zealand (KiwiRAP 2010). It is not likely to be applicable in Australian conditions.

- Australian National Risk Assessment Model (ANRAM) – utilises iRAP’s SRS algorithms in risk assessment, but incorporates a fatal and serious injury crash prediction module based on Australian crash data to estimate the risk level. Under the ANRAM model, changes in speed will be reflected in the expected number of fatal and serious injury crashes. ANRAM is intended for adoption by all Australian jurisdictions (Austroads 2013a).
- Road Safety Risk Manager (RSRM) – adopts an engineering risk assessment approach to prioritise proposed treatments, with the aim of maximising crash risk reduction on the road network for a given budget. RSRM is not a road or network assessment tool.

It would be reasonable to conclude that none of the above methods meets all of the desired decision support system criteria. The main reasons are the high levels of data and user resources needed to assess the risk. NetRisk may be an exception in this regard; however, its use has not been extended to all road environments (e.g. urban roads).

4.2 Severe Crash Risk Factors (Features of Higher-risk Roads)

Accounting for the role of key road environment variables in both crash likelihood and severity can assist in developing quantitative parameters for risk-based speed limit guidelines. If the level of safety provided by the road is inadequate and cannot be easily improved, speed management techniques may be applied to improve the overall level of safety.

Austroads (2008a) suggests that collective risk, or crash rate per kilometre, should be used in speed limit reductions with caution. This issue was explored in Section 3.5.1. The effect of speed variation on casualty crash risk was discussed in Section 3.3. The disparity between the mean speed and speed limit can be a source of speed variation.

To date, there have been few investigations of the relative risk of fatal and serious injury crashes. The majority of published information on crash reduction factors or crash modification factors relates to casualty crashes, or all-severity crashes.

The summarised findings in Table 4.1 draw on the investigations presented by Jurewicz and Zivanovic (2011) and Austroads (2010a, 2010d). The results were based on several available data sources from Queensland, Victoria and New South Wales. Table 4.1 demonstrates the relative impacts of some of the key road features and operational factors on severe crash likelihood. Their impacts on the overall severity of reported casualty crashes are also presented (FSI ratios)⁸. Appendix A provides a compendium of the severe risk factors arranged by road environment. Appendix B provides the detailed findings of the literature reviews and data analyses. These appendices also include risk exposure factors based on AADT. These factors relate to the collective risk of severe crashes.

The source data was not available for all road environment types, but the findings provide an indicative range of mostly severe crash risk factors for consideration in the model risk-based guidelines. These risk factors overlap with many factors currently used in speed limit setting, detailed in Austroads (2008a, 2008b) and in Standards Australia (2008).

Care was taken to present the risk factors that were relevant to safety performance at a road-section level, rather than at individual locations only. This approach was considered more relevant to speed limit setting.

It is also noted that detailed error analysis was not carried out as part of the review and analysis. Hence, the accuracy of individual values listed in Table 4.1 cannot be quantified. Nevertheless, most risk factors indicate logical relationships, which are reflected by the current road design guidance (e.g. a lower crash risk with wider sealed shoulders).

⁸ This severity index is the ratio of fatally and seriously injured persons to all persons involved in casualty crashes on the sample of roads with the given feature. This index is sometimes referred to as the FSI ratio. An FSI ratio of zero would represent a Safe System ideal – no casualty crashes resulting in severe injuries.

The data samples used in the analysis were drawn from Victoria, Queensland and New South Wales. The data sets used in the analysis were based on many kilometres of roads in each stereotype and included large numbers of crashes. It needs to be noted that the findings from one jurisdiction may not always apply in others, and for this reason, the severe crash risk factors should be treated as indicative.

The top severe crash risk factors that emerged from the review and analysis were:

- Rural roads
 - unsealed pavement
 - single carriageway
 - narrow sealed shoulders (< 1 m) (risk was offset somewhat by the presence of unsealed shoulders)
 - high frequency of curves (more than 20 per 10 km, based on casualty crashes)
 - narrow clear zone (< 2 m)
 - undulating terrain (based on casualty crashes)
 - frequent or continuous roadside hazards (> 50 per 100 m)
 - all intersection types with the exception of roundabouts
 - steep embankments (i.e. steeper than 1:3).
- Urban roads
 - commercial urban land use
 - high numbers of crossing pedestrians or cyclists in traffic (based on casualty crashes)
 - narrow sealed shoulders on single-carriageway roads (where provided)
 - presence of controlled and uncontrolled intersections, with the exception of roundabouts.

Table 4.1: Summary of severe crash risk factors

Road environment feature	Categories	Relative risk of fatal and serious injury crashes	Severity index	Notes
Pavement type	Sealed (rural)	1.00	0.32	Single carriageway rural roads, 100 km/h speed limits.
	Unsealed (rural)	2.53	0.28	
Traffic flow	Single carriageway (rural)	1.4 times higher on AADT 1000 vpd roads than on AADT 5000 vpd roads	Increases slightly on rural roads with high AADT	Based on 100 km/h roads. Please note the risk exposure factors in Appendix A.
Traffic flow (cont.)	Single carriageway (urban)	1.9 times higher on AADT 1000 vpd roads than on AADT 14 000 vpd roads	Constant	Based on 60 km/h roads, the correlation was much weaker. Please note the risk exposure factors in Appendix A.
Pedestrians crossing per day (urban)	10	1.02*	n.a.	Based on AADT of 10 000 vpd and a 100 m section; represents risk of pedestrian casualty crashes.
	20	1.22		
	50	1.54		
	150	2.04		
	300	2.44		
Cyclist flow along per day (urban)	100	1.49*	n.a.	Based on AADT of 10 000 vpd and a 1 km section.
	200	1.74		
	500	2.15		
	1000	2.52		
	4000	3.46		

Road environment feature	Categories	Relative risk of fatal and serious injury crashes	Severity index	Notes	
Abutting land use	Industrial (urban)	1.00	0.26	Based on single carriageway, two-lane, urban roads with a 60 km/h speed limit.	
	Residential (urban)	1.02	0.22		
	Commercial (urban)	1.42	0.22		
Frequency of property entrances and intersections	Urban roads (built-up areas)	$1.00 + 0.25 \times \text{no. accesses per } 100 \text{ m}^*$	Likely to increase with access density	Based on all casualty crashes.	
Median presence and width	Dual carriageway (rural)	1.00	0.24	Greater median width appeared to produce lower overall crash risk on 80 km/h roads.	
	Single carriageway (rural)	2.97	0.31		
	Dual carriageway (urban)	1.00	0.19		
	Single carriageway (urban)	1.36	0.23		
Lane width	Urban and rural	Inconclusive	Inconclusive	Casualty crash likelihood decreased with increasing lane width for sealed undivided rural roads with 100 km/h speed limits.	
Sealed shoulder width	Rural, single carriageway			Based on single carriageway rural roads with 100 km/h speed limit. Unsealed shoulders were shown to provide additional reductions in run-off-road casualty crash risk.	
	0.5	1.69	0.34		
	1.0	1.37	0.32		
	1.5	1.18	0.31		
	2.0	1.00	0.31		
	Urban, single carriageway			Based on single carriageway roads, 60 km/h speed limit.	
	0.5	3.09	0.21		
	1.0	2.75	0.27		
	1.5	1.50	0.21		
	2.0	1.00	0.17		
Urban, dual carriageway			Inconclusive	Slightly increasing	Divided urban 70–80 km/h roads.
Parking lanes	Urban, single carriageway			Based on 60 km/h urban roads only.	
	Yes	1.02	0.15		
	No	1.00	0.21		
Parking lanes (cont.)	Urban, dual carriageway			Based on 60, 70 and 80 km/h urban roads only.	
	Yes	1.27	0.22		
	No	1.00	0.20		
Clear zone (rural)	0–2 m	2.27	0.62	Based on 100 km/h rural single carriageway roads (barriers excluded).	
	2–4 m	1.13	0.47		
	4–8 m	1.03	0.55		
	> 8 m	1.00	0.54		
Hazard density (rural)	< 8 per 100 m	1.00	0.45	Based on 100 km/h single carriageway rural roads in Victoria (barriers excluded). Continuous flexible barriers were shown to deliver strong crash likelihood reductions.	
	8–25 per 100 m	1.11	0.60		
	25–50 per 100 m	1.16	0.57		
	> 50 per 100 m or continuous	1.73	0.60		
Horizontal curve frequency per 10 km (rural)	1	1.03*	n.a.	Based on casualty crashes, rural single carriageway roads.	
	5	1.14			
	10	1.30			

Road environment feature	Categories	Relative risk of fatal and serious injury crashes	Severity index	Notes
	20	1.71		
	40	2.86		
	60	4.46		
Terrain (rural)	Undulating	4.5*	n.a.	Casualty crash rate approximately 4.5 times higher in undulating road terrain than on flat road.
Intersections	Rural, 3-leg roundabout	1.00	n.a.	Examples only.
	Urban, 3-leg, signals	2.02		
	Rural, 4-leg, signals	2.83		
	Rural, 3-leg, unsignalised	3.34		
	Rural, 4-leg, unsignalised	4.68		

* Based on casualty crashes, rather than fatal and serious injury crashes due to limited available information and data.

Note: Appendix A presents these results sorted by urban/rural road environments. Please refer to Appendix B for details of the results presented in this table.

There are many other road features and risk factors that influence the likelihood and severity of crashes and could be potentially considered for inclusion in speed limit guidelines. Many of these, although considered under current practice, were not quantified due to a lack of available research evidence or data for analysis. These and other identified knowledge gaps are detailed in Section 11.

4.3 Examples of Higher-risk Roads

This section summarises a selection of research literature dealing with examples of roads with an increased risk of crashes. The literature review focussed on the applicability of lower speed limits along such road sections.

There are various types of roads with an increased crash risk that can be made safer by the application of lower speed limits. Crash risk can be higher on roads where motorists are transitioning from one speed environment to another, or where there is a high speed differential. The type of road user can also affect the crash; for example, tourists unfamiliar with the road conditions, or inexperienced drivers on unsealed roads. Crash risk can be heightened during certain times of the day (e.g. school times) or seasons (e.g. peak tourist or harvest times).

Appendix C provides details of the review of higher-risk roads, as summarised below:

- pedestrian activity zones (including school zones, strip shopping centres)
- high volume outer urban arterials
- transitions between speed environments
- tourist or motorcycle routes
- uncontrolled rural intersections
- railway crossings
- narrow bridges/one-lane bridges
- freeways
- rural unsealed roads.

5. Review of Current Guidelines for Setting Speed Limits on Higher-Risk Roads

Existing speed limit setting practices in Australia and New Zealand already consider a range of factors such as crash history, operating performance, road geometry, and abutting development. The combination of these factors determines the level of crash risk of a particular road.

The purpose of this section is to review how the existing speed zoning guidelines relate to setting speed limits on higher-risk roads and at intersections. Review of the available guidelines and discussions with the relevant road agency experts has informed the content of this section.

5.1 Australian Guidelines

Guidance on setting speed limits is provided by:

- Australian Standard 1742.4-2008 Manual of Uniform Traffic Control Devices – Part 4: Speed Controls (Standards Australia 2008)
- Guide to Road Safety – Part 3: Speed Limits and Speed Management (Austroads 2008a)
- Guide to Traffic Management – Part 5: Road Management (Austroads 2008b).

5.1.1 Standards Australia

Standards Australia (2008) provides guidance on how speed limits should be determined and applied in various situations. The primary speed limit is determined by the road function. It describes typical applications of different speed limits and their associated characteristics.

The Australian standard also enables adjustments to be made according to a number of factors. These factors include:

- Roadside development, both the type (e.g. rural, commercial) and density.
- Road characteristics including alignment, cross section, sight distances, frequency of access points and intersections, and parking.
- Traffic characteristics such as traffic volume, composition and patterns.

An adjustment to the speed limit due to crash history is also permitted under the standard, if the crash data indicates a general crash pattern along a road, and the casualty crash rate is significantly higher than average. If a feasible engineering treatment to address the issue cannot be established, then a lower speed limit may be considered.

The standard references Austroads (2008a) as the source document for setting speed limits.

5.1.2 Austroads Guidance

Austroads (2008a, 2008b) provides a general philosophy and the processes for speed limit setting where there is a high probability of conflict between various road users, and therefore, a higher likelihood of crashes. Urban areas with abutting developments generating substantial vehicle and/or pedestrian movements fall into this higher-risk category and attract lower speed limits. Typically, these road types include roads in CBD areas, around schools, around shopping centres, and roads that experience large seasonal traffic variations. Where vehicle travel speeds are found to be significantly higher than the assessed speed limit, engineering treatments designed to constrain vehicle speeds may be considered.

Austrroads (2008a) emphasises that speed limits should not be reduced to address localised safety deficiencies in lieu of engineering treatments. Austrroads (2008b) states that where the speed limit exceeds the maximum safe travel speed at an isolated location, warning and advisory speed signage should be utilised.

Austrroads (2008a) notes a number of factors associated with higher risk where reduced speed limits may be considered. These include: high crash rates (individual risk), roadside hazards, uncontrolled intersections and access points, and opportunities for collisions between motor vehicles, pedestrians and cyclists. A lower speed limit may be considered where there are a series of hazards along an extended length of road.

A number of jurisdictions have developed their own speed zoning supplements to the Austrroads Guides to reflect their specific local conditions, requirements and practices. Details on the elements of these practices that refer to setting speed limits on higher-risk roads, and at intersections, are provided in the following sections. Many jurisdictions use computer-based X-LIMITS decision support systems, which assist practitioners in the consistent and objective assessment of speed limits. The X-LIMITS system mirrors jurisdictional speed setting guidelines in recommending a speed limit.

The Northern Territory and Australian Capital Territory do not have their own speed zoning guidelines, and rely solely on Standards Australia (2008).

5.1.3 Roads and Maritime Services, New South Wales

Roads and Traffic Authority (2011) guidelines assist in determining permanent speed limits. The guidelines contain a section on higher-risk locations, defined as:

...a location along the road network where there were road geometry constraints, hazards in the roadside, non-conformance with design standards for the proposed speed zone, or a perceived or identified risk.

Key factors for such locations are road geometry, intersections with potential conflict points, road alignment, and crash history. The guidelines recommend a route-based approach to these higher-risk road locations to ensure the speed limits are consistent with the road environment. The length of at-risk speed zones is allowed to be shorter than the desirable minimum speed zone lengths to reduce impacts on mobility. Speed limit signs for these higher-risk locations must have additional supplementary plates displaying the risk.

Separate guidelines for 40 km/h speed limits in high volume pedestrian areas provide criteria for identifying suitable locations, possible treatment option, and the implementation process (Roads and Traffic Authority 2005). The guidelines apply to local, regional and state roads. The guidelines state that consideration of a 40 km/h speed limit is appropriate in zones that generate significant pedestrian traffic, including:

- CBD areas
- suburban shopping strips
- beachside or park reserves, where facilities generate significant pedestrian traffic
- medical centres, hospitals and government service agencies (business areas generating significant pedestrian traffic).

The guidelines highlight that pedestrian movements on the road are the key criteria, so developments with access points that deliver pedestrians directly onto the road should be considered in the speed limit decision. There are a number of criteria that need to be satisfied in different categories to determine if a location is suitable for a pedestrian precinct treatment with a lower speed limit. These include proximity to public transport, and what type of businesses the road is providing access to. The selection of treatment options is then determined by the road category (local, regional, state), function (if the road is a principal travel route), and existing speed environment. Treatment options can include a combination of a 40 km/h speed limit, gateway treatments, and traffic calming treatments or measures to maintain pedestrian-vehicle separation.

An audit of speed limits on over 100 roads was undertaken in New South Wales during 2011. The audit recommended 'streamlining' speed limits on 12 key routes, where there were frequent speed limit changes along the road length. The speed limits on four highways (Princes Highway, Great Western Highway, Pacific Highway and Newell Highway) were increased as part of the review, while seven roads were to have their speed limits decreased.

5.1.4 VicRoads, Victoria

The speed zoning practice in Victoria is contained within the *Speed Zoning Guidelines* (VicRoads 2010). Victoria takes the Safe System approach to speed limit setting, and recognises that the road transport system needs to be designed, built and speed limited so that when crashes occur, people are not fatally or seriously injured.

Many factors are taken into account in determining the maximum safe speed limit for roads in Victoria, including:

- road characteristics (function, presence of median, pavement width, geometry)
- extent and nature of abutting development (development type and density, type of traffic generated)
- road users (their movement and potential conflicts between users)
- crash history
- seasonal issues (holiday and harvest traffic, ice or snow on road).

At high-risk locations, where risks are deemed to be 'unacceptably high and infrastructure improvements are not feasible, the guidelines state that speed reduction may be appropriate. The guidelines also state the importance of taking site-specific, local and route factors into consideration when deciding on an appropriate speed limit.

The speed limit can be adjusted from the rural default speed limit of 100 km/h in some circumstances, as suggested by the VLimits 2.0 program. The key risk variables determining the reduced speed limit for rural roads are the abutting environment (lower speed limits in sparsely and partially built-up areas and in hamlets) and driveway access frequency. Other factors such as crash history, road geometry, and roadside features are also considerations. Other speed limit reductions on higher-risk roads are also covered by VicRoads (2010), namely:

- The speed zoning guidelines allow reduction of the speed limit to 50 km/h in the commercial centres of rural and outer metropolitan town centres to improve driver, passenger and pedestrian safety. The candidate locations are eligible on the basis of their minimum length, crash history, and evidence of pedestrian activity.
- Time-based 40 km/h speed limits apply in Melbourne's busiest strip shopping centres. These were set during high activity hours and as suggested by pedestrian crash times. The guidelines require that these speed limits are clearly marked with electronic variable speed signs and advance warning signs. The speed limit may revert back to 60 km/h when the 40 km/h during the higher-risk period for pedestrians is not applicable.
- Time-based 40 km/h school speed zones are used on all roads abutting school gates. They are prescribed for drop-off and pick-up times on gazetted school days only (8–9:30 am and 2:30–4 pm). On local streets where a default urban speed limit is applicable, the school zones apply at all times.
- A reduced speed limit of 40 km/h may be used in local residential areas where pedestrian and cyclist safety are a concern, and where the road design supports the lower speed (e.g. traffic calmed streets).
- In car parks and recreational reserves/parks, a speed limit of either 30 km/h or 40 km/h may be used, often together with traffic calming (usually speed humps).
- Speed limits on the approach to all at-grade railway level crossings on sealed arterial roads with speed limits greater than 80 km/h were reduced to 80 km/h in 2007. A similar program was to be completed on sealed local roads by the end of 2012–13.

The outcomes of the 2011–12 Victorian speed limit review were announced in August 2012 (VicRoads 2012). The 12 adopted recommendations were to simplify speed zoning in Victoria (e.g. removal of 70 and 90 km/h speed limits), to broaden the application of 40 km/h speed limits in pedestrian areas, and to help road users to understand and comply with speed limits through reduced frequency of their changes. At the time of writing, the Victorian guidelines (VicRoads 2010) were still under revision.

5.1.5 Department of Transport and Main Roads, Queensland

The Queensland guidelines list crash history as a potential factor in consideration of lower speed limits, but require that other considerations for reducing the risk be exhausted first (Department of Transport and Main Roads Queensland 2011).

On undivided rural roads, where design speed and other parameters are less than 100 km/h over a length of at least 2 km, and the general speed limit is not appropriate, the guidelines recommend that a lower speed limit should be considered. It is recommended that the prevailing speed should be the basis for the speed limit.

The speed zoning guidelines allow application of lower speed limits on long road sections of rural residential roads with speed limits over 50 km/h where the road design is compatible with lower a speed limit.

Additionally, there are a number of criteria where lower speed limits are applicable in implied recognition of higher crash risk. These include:

- 40 km/h on
 - local streets designed to support the lower speed limit, or traffic-calmed
 - traffic carrying roads through strip shopping centres with appropriate traffic calming
 - low-speed central business district streets with significant pedestrian activity
 - roads adjacent to significant generators of pedestrian activity at certain times of the day
- 50 km/h on
 - traffic-carrying roads that are constrained or changed physical speed environment
 - foreshore esplanades that are not major traffic routes
- for certain classes of vehicle for safety reasons (e.g. road trains)
- at intersections with a high crash history or high potential crash risk, lower speed limits can be applied
 - on roads with speed limits of 80 km/h and above, a 60 km/h limit can be applied on a controlled approach⁹
 - on an uncontrolled approach, a speed reduction of up to 30 km/h may be applied. The length of the speed zone shall not exceed 300 m.

Additionally, the guidelines recognise higher-risk roads through assessment of crash risk factors during a regular speed limit review process. A lower speed limit may be recommended where roadside development, access and intersection density, or lack of a dividing median or turning lanes are detected. This practice is typical of the existing speed limit approach based on AS 1742.4-2008 (Standards Australia 2008) and Austroads (2008a). Queensland Transport and Main Roads operate an online tool called SLR-QLIMITS 3.0, which assists practitioners in the consideration of multiple risk factors. The software also uses crash rate costs derived from all crashes to calculate the crash rate as an indicator of risk.

⁹ A controlled approach is one in which the traffic is controlled by signals, stop sign or give way sign.

5.1.6 Main Roads, Western Australia

Main Roads WA (2012) provides guidance on reductions in speed limits at higher-risk locations. The relevant information on road sections, intersections, single-lane bridges and floodways is as follows:

- Road lengths
 - Where several roadside hazards are in close proximity to each other on road sections over 3 km in length, a lower speed limit may be applied than suggested by the speed environment.
 - Curving road sections over 3 km in length, where Winding Road warning signs need to be used, shall be speed zoned on the basis of the operating speed.
 - If advisory speed signage is used, and the crash rate is higher than the network average for the road type, then a lower speed limit may be applied.
 - For road sections with a high incidence of crashes, due to poor traffic conditions or road hazards, a lower speed limit can be considered where the section cannot be treated in a reasonable period of time, or the reason for the crashes is not apparent.
- Intersections
 - At traffic signals and roundabouts on roads that are speed zoned at 90 km/h and above, a lower speed limit (80 km/h or lower) on the approach shall be applied, at least 300 m before the intersection.
 - On divided carriageways, if offset speed zones are appropriate, the length of the speed zone should be reduced to 100 m on the departure side of the feature.
- Single-lane bridges/floodways
 - A lower speed limit (80 km/h or lower) applies at least 300 m before the bridge/floodway. On divided carriageways, the lower speed limit also applies 100 m after the bridge/floodway.

In addition to the lower speed limit, traffic control devices should be provided due to the potential for high severity head-on crashes at single-lane bridges/floodways.

Main Roads WA (2012) also allows establishment of 40 km/h speed zones and areas in response to the risk to pedestrians and cyclists. All roads within such areas must be contained within a recognised shopping, commercial, industrial, tourist, recreation or conservation precinct /reserve. The traffic volume on all roads within such an area must exceed 100 vpd and must meet geometric and traffic calming requirements.

5.1.7 Department of Planning, Transport and Infrastructure, South Australia

The Department of Planning, Transport and Infrastructure (DPTI) speed zone setting practices are based on Austroads (2008a, 2008b) and Standards Australia (2008). DPTI practice also permits lower speed limits to be applied along high crash risk or high crash severity locations. Such applications include:

- Use of 40 km/h on designated networks of local roads. These roads are considered as higher-risk areas due to the large number of pedestrians and cyclists present. Some holiday home areas, for example Yorke Peninsula, also have 40 km/h speed limits (Department of Planning, Transport and Infrastructure 2013).
- A speed limit of 25 km/h:
 - on a portion of road within a school zone when a child is present
 - between the signs at a children's crossing when the alternating yellow lights are flashing
 - when passing, in either direction, a school bus that has stopped to pick up or set down passengers
 - when passing roadworks with signs advising of works is displayed.

Lower speed limits may also be applied at higher-risk locations as follows (Department for Transport, Energy and Infrastructure 2008):

- along roads with extended lower limits in hilly terrain, e.g. Fleurieu, Barossa and Adelaide Hills
- in order to align rural speed limits to the design standard of the road.

5.2 New Zealand Guidelines

In New Zealand, Road Controlling Authorities (RCAs) are responsible for setting speed limits on roads under their jurisdiction, in accordance with the *Land Transport Rule: Setting of Speed Limits 2003* (New Zealand Transport Agency 2004). RCAs consist of a group of local city councils, district councils and the New Zealand Transport Agency that controls the state highways. Speed limits are set in multiples of 10 km/h between 20 and 100 km/h, as well as holiday (seasonal), temporary, and variable speed limits.

New Zealand Transport Agency (2004) is the standard guideline document used for assessing suitable speed limits, which considers a variety of development and roadway factors. Public consultation is also necessary as part of the process and specific groups such as the New Zealand Transport Agency, the NZ Police, the Automobile Association, and the Road Transport Forum were informed of any proposed changes.

Rural speed zoning involves speed limits being set according to the physical characteristics of the road and its operating conditions. For example, a narrow, winding, mountainous section of road may justify a lower speed limit.

The guidelines also state that crash history and selected higher-risk road features should be considered in speed limit setting, but provide no clear input of crash history in speed limit selection. Rather, the guidelines provide a weighting system where the presence of some higher-risk road features may result in a lower speed limit.

As part of a trial, risk-based guidelines were developed for lower speed zones on rural roads. Speed limits were reduced on selected sections of rural road where there was adverse road geometry. These trials are detailed in Section 6.2.4.

Speed limits may be also varied seasonally in some New Zealand tourist destinations. These are called 'holiday speed limits' and are defined as 'a lowered speed limit through a popular holiday destination...during a busy holiday period' (New Zealand Transport Agency 2009). These are applied to locations where crash risk increases at different times of the year due to roadside activities and increased exposure. Generally a 50, 70 or 80 km/h holiday speed limit is applied.

5.3 International Guidelines

Speed limit setting guidelines in selected countries, with a particular focus on guidance at higher-risk locations, is provided in the following sections.

5.3.1 United Kingdom

Any single-carriageway road where there is no street lighting has a default speed limit of 60 mph (97 km/h) in the UK, often referred to as the 'national speed limit'. This applies in the absence of signs indicating any other speed limit.

A speed limit policy *Setting Local Speed Limits* was released by the UK Department for Transport (DfT) in 2006 (Department for Transport 2006). The speed limit assessment framework is designed to help determine the appropriate speed limit on the basis of casualty reduction, as well as economic, social, and environmental effects. The policy states that speed limits in rural areas should be set based on the following factors:

- the mean speed (this is a change from the previous policy, where the 85th percentile speed was used)
- road function, characteristics and environment
- local conditions and constraints
- crash rates
- minimum costs in terms of safety, mobility and the environment.

Under the strategy, higher-risk locations are identified and lower speed limits are set on these roads as follows:

- For local access roads that have a high number of junctions and accesses, a lower speed limit should be applied.
- For roads with substandard road alignment, i.e. where there is a high density of bends or the road is hilly, lower limits should be applied.

Higher speeds should be used for higher-quality roads.

Speed limits on upper tier roads, which cater primarily for through traffic, and on lower tier roads, which have a local or access function, are determined based on crash rate, as follows:

- Upper tier roads with a crash rate less than 35 injury crashes per 100 million VKT have a 60 mph (97 km/h) limit.
- Upper tier roads with a higher crash rate will have a lower speed limit, typically a 50 mph (80 km/h) limit.
- Lower tier roads with a crash rate of below 60 injury accidents per 100 million VKT, have a 50 mph (80 km/h) limit.
- Lower tier roads with a higher crash rate have a 40 mph (64 km/h) limit.

The policy does not indicate whether or not infrastructure measures were required that were supportive of lower limits.

5.3.2 Sweden

Decisions on speed limit setting in Sweden are undertaken by national agencies, regional councils and local municipalities depending on the tier of roads to which the limits apply. The Swedish Transport Administration (STA) can increase the speed limit if the road conditions and environment are at a certain standard, defined by a number of criteria. The regional councils have the authority to decrease speed limits in small villages and at high-volume intersections. Municipalities also have the authority to review and change the local road speed limits within their urban area, and on state through roads within the municipality. However, to date only a small proportion of municipalities have made changes to urban speed limits.

Swedish Transport Administration (2011) details speed limit practice. It states a general philosophy that speed limits should conform to road standards so that they are perceived as reasonable, compliance is good, and the driving conditions are comfortable for all road users.

The speed limit system had changed little since the early 1970s until a recent review. In 2008–09, the STA introduced new speed limits that were aligned with how safe the road is and with the physical tolerances of the human body in a crash. The STA aimed to strike a balance between road safety, environment, mobility, accessibility and regional development (Svensson 2010).

The STA consulted with county administrative boards, municipalities, police and regional development councils regarding the proposed speed limit changes. The STA then took a high-level decision on changing the speed limits in all regions (Svensson 2010).

As part of the review, some speed limits were raised in the southern regions of Skåne and Västra Götaland. Meanwhile, speed limits were lowered on long stretches of the two European Highways E12 and E45 (Svensson 2010).

At the time of the review, the general speed limit outside of urban areas was 70 km/h. The typical speed limits applicable on various road types were as follows (personal communication, Torsten Bergh of STA, 16 September 2011):

- On motorways in rural areas, the speed limit was mostly 110 km/h, although some roads were 120 km/h.
- Divided (median-separated) roads had a speed limit of 100 km/h; the exception was low-volume roads, which may have a 110 km/h speed limit.
- Two-lane undivided roads had a speed limit of 80 km/h, except on low volume roads (< 2000 vpd) that were deemed 'important', which have a 100 km/h speed limit.
- In cities and villages the top speed limit was 40–50 km/h.
- Around schools and day-care centres, and in CBD areas, the speed limit was 30 km/h.
- On 2+1 roads, the limit was between 110 km/h and 70 km/h.

The 2+1 roads consist of two lanes in one direction, and one lane in the other, alternating every few kilometres with a steel cable barrier separating the traffic flows. These roads were first successfully trialled in 1998 and became widely used throughout Sweden. Swedish guidelines recommend speed limits of 110 km/h for new 2+1 roads on semi-motorways, and speed limits of either 90 km/h or 110 km/h for new conventional 2+1 roads. A lower speed limit of 80 km/h is applied to trucks on 2+1 roads (National Cooperative Highway Research Program 2003). A lower speed limit is also applied on the approach to intersections on 2+1 roads, usually from 100 km/h to 70 km/h.

Guidelines for speed limits at higher-risk locations recommend (personal communication, Torsten Bergh of STA, 16 September 2011):

- electronic variable message signs displaying reduced speed limits at rural intersections where secondary road traffic volumes were above 1000 vehicles per day
- lowered speed limits on road sections with high pedestrian and cyclist usage, short crosswalks and parking areas
- a 30 km/h default speed limit on local and residential roads within city centres; this was introduced in Stockholm by the Stockholm City Council in 2007.

5.3.3 Netherlands

The speed limit policy in the Netherlands is aimed at safety and credibility (personal communication, Hilke Harms of ARRB, 9 September 2011). The key concepts are:

- The speed limits need to be safe, given the circumstances and traffic composition, i.e. that it is almost impossible that a crash will result in severe injury.
- The speed limits are credible, i.e. the speed limit and transitions fit how the road looks.
- The driver has sufficient information about the local speed limit.

The speed limits for various road types were defined in the Dutch Road Traffic Law (Wegenverkeerswet) as follows (Schagen, Wegman & Roszbach 2004):

- freeways – 120 km/h
- highways – 100 km/h
- most rural roads – 80 km/h
- rural access roads – 60 km/h (along with traffic calming measures, gateway signage, road width restrictions)
- built-up areas – 50 km/h.

However, at many higher-risk locations, the speed limits differed from those stated in the Dutch Road Traffic Law in order to improve safety (personal communication, Hilke Harms, 9 September 2011). These include:

- Higher-risk locations on freeways
 - The speed limit can drop from 120 km/h to 100 or 80 km/h; about 40% of the freeway network has a speed limit of 100 km/h.
 - At curves on freeways, the speed limit can drop to 90 km/h.
 - The speed limit is reduced to 80 km/h close to cities.
 - At connections between two freeways, i.e. freeway off-ramps, the speed limit can be reduced to 50 km/h on a curve (speed limit reductions are applied in steps from 100 to 90 to 70 to 50 km/h).
 - Where traffic volumes are high, the speed limit can be lowered from 120 km/h to 100 km/h (by road agencies).
- Higher-risk locations on highways
 - The speed limit is 80 km/h at high-risk road sections.
 - The speed limit is 70 km/h at specific higher-risk locations.
- Rural roads
 - At traffic lights, the speed limit drops to 70 km/h.
 - At higher-risk road sections, the speed limit can drop to 60 km/h.
 - At higher-risk locations on rural roads, the speed limit drops to 60 or 50 km/h.
 - At schools or other locations with a lot of pedestrians or cyclists, or a location with a sharp curve, the speed limit is 30 km/h.
- In built-up areas

The speed limit is 30 km/h or 20 km/h for shared spaces, neighbourhood roads, and shopping centres.

5.3.4 Germany

Speed limits in Germany differ according to road type. The Federal Ministry of Transport, Building and Urban Development (2010) provided information on the various speed limits. Rules concerning legal speed limits have not been revised for the last 30 years (personal communication, Marco Schmidt, Federal Highway Research Institute (BAST), 28 September 2011). The general philosophy is that specific speed limits should only be used on sections where traffic observations or crash history show that it is necessary for road user safety.

Speed limits on the autobahn network, roads outside built-up areas, and local roads are detailed below. Guidance on setting speed limits at higher-risk locations is also provided. Information on where speed limit trials were undertaken on motorways in Germany is provided in Section 6.

Autobahn network

Germany's philosophy is that 'motorways should be planned, designed and equipped in such a way that it is possible to drive at the recommended speed of 130 km/h in a passenger car without danger' (personal communication, Marco Schmidt, BASt, 28 September 2011).

The European Transport Safety Council (2008) reported that there were no mandatory speed limits on over half of Germany's autobahn network; however, there was a 'recommended' top speed of 130 km/h. Temporary speed limits due to weather or traffic conditions applied on 15% of the network, while only 33% of the autobahn network had permanent speed limits.

Special speed limits, below the level of the recommended speed, were applied on sections of the motorway network to ensure the speed was compatible with the road environment. These limits were applied on higher-risk road sections that were characterised by:

- roads with extreme longitudinal gradients, narrow unexpected bends, limited sight distance or limited lane width
- high traffic volumes and high risk of congestion – the speed limit was usually set at 100 km/h but could be reduced further to 80 km/h or 60 km/h as traffic volumes increased, in order to smooth traffic flow (variable speed limits)
- unsuitable physical road condition – road surface damage on traffic lanes, or other permanent or temporary dangers (e.g. aquaplaning)
- significant crash history
- when hard shoulder running was operating (speed limits reduced to 100 km/h).

Approximately one-third of motorways had these special speed limits in 2006. The rate of fatalities corresponds to the portion of the motorway with a speed limit applied; in 2006 and 2007, the Federal Statistical Office reported that 32% of total fatalities were on sections with a speed limit.

Motorway speed limits for different vehicle classes

There were different speed limits for different vehicle types such as motorcycles, buses, and vehicles towing trailers (Federal Ministry of Transport, Building and Urban Development 2010). They applied on motorways within built-up areas and on divided roads outside built-up areas, as follows:

- 100 km/h for motor coaches and buses without a trailer
- 80 km/h for vehicles over 3.5 tonnes, and vehicles (passenger cars, lorries, motor homes, tractors) towing a trailer, also motor coaches and buses (with or without a luggage trailer)
- 60 km/h for motorcycles and self-propelled machines towing a trailer, and tractors towing two trailers
- 60 km/h for motor coaches and buses towing a trailer and/or carrying standing passengers.

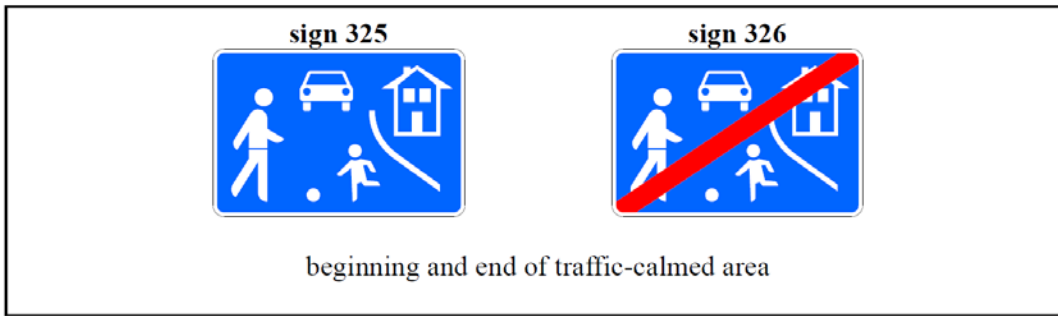
Local roads

The Federal Ministry of Transport, Building and Urban Development (2010), states that the maximum permissible speed for all vehicles is 50 km/h within built-up areas.

Nearly 30 years ago, physical restrictions combined with lower speed limits were introduced, which assisted in lowering vehicle travel speeds. This involved the installation of traffic-calming devices such as chicanes, kerb extensions, and speed humps, in residential areas and villages.

The 30 km/h speed zones are used for areas with a high density of pedestrians and cyclists, and where a large number of people need to cross the road. These are advertised by special traffic signs used to warn motorists of the change in speed zone. Under special circumstances, road agencies can install traffic-calmed areas where vehicular traffic must move at walking pace (Figure 5.1).

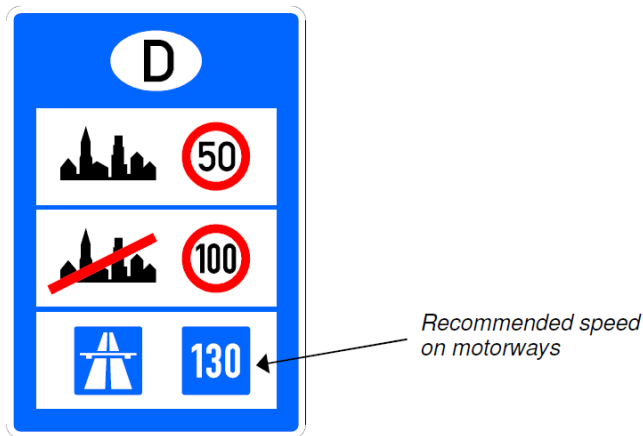
Figure 5.1: Signage used for beginning and end of traffic-calmed areas



Source: Federal Ministry of Transport, Building and Urban Development (2010).

The information board, which displays the speed limits for different road types, is shown in Figure 5.2.

Figure 5.2: Information board on border crossing points



Higher-risk locations

Lower speed limits were applied according to the road conditions, the type of hazards present, the road characteristics and the visual road environment. The prevailing speed of the road section, as determined by the 85th percentile speed, is taken into account where a speed limit reduction is deemed necessary. The speed limit chosen should not be exceeded by 85% of the motor vehicles. Some examples of where lower speed limits were applied at higher-risk locations are given in Federal Ministry of Transport, Building and Urban Development (2010):

- For road sections with curves or limited sight distance, speed limits could be reduced so that in wet conditions the speed limit matches the safe speed for the curve.
- For intersection approaches or crossroads with traffic signals outside built-up areas, speed limits could be reduced to 70 km/h or 50 km/h where necessary.
- If visibility is less than 50 m due to fog, snowfall or rain, motorists must not drive faster than 50 km/h, or at a considerably lower speed where circumstances so require.

5.3.5 USA

The speed limit Guidelines in the USA varies between states. No national guidelines on speed limit setting at higher-risk locations could be identified. The *Manual of Uniform Traffic Control Devices* (Federal Highway Administration 2013) is the national standard for signing on highways, including regulatory speed limits, advisory speed signs, school zone speed limit signs, and work zone speed limits.

Speed limits vary according to road hierarchy, as follows:

- highway speed limits – mostly 70 mph (112 km/h), with some at 75 mph (120 km/h)
- collector roads – usually 55 mph (88 km/h) or lower
- local roads – speed limits 35 mph (56 km/h) or lower.

The web-based expert speed zoning system USLIMITS2 was created to assist practitioners to analyse segments of roads and set speed limits that are appropriate and consistent. The system recommends a speed limit for a section of road based on road function, roadside development, operating speeds, road characteristics and crash rates (Federal Highway Administration 2013). It is applicable for rural and urban roads, local roads and urban freeways. Application of the tool has led to recommendation of lower speed limits on higher-risk road lengths, e.g. where there was high frequency of intersection or access points. The system also considers crash rates and compares them with typical values for each road environment.

5.3.6 Season-dependent and Weather-dependent Speed Limits in Europe

Season-dependent and weather-dependent variable speed limits are used in many European countries. The variable speed limits are only applied to roads at high risk of suffering inclement conditions. European Conference of Ministers of Transport (2006) provided a French example of reduced speed limits applied in inclement weather conditions:

- When rain or snow was present, the speed limits were reduced from 130 km/h to 110 km/h on motorways and 90 km/h to 80 km/h on rural roads.
- In foggy conditions, when visibility was less than 50 metres, the speed limits were reduced to 50 km/h on all roads.

An evaluation of the effectiveness of these speed limit reductions was not available at the time of writing.

European Commission (n.d.) provided examples of the Finnish practice of seasonal limits:

- On freeways/motorways, the speed limit was 120 km/h in summer and 100 km/h in winter.
- On rural roads, the speed limit was 100 km/h in summer and 80 km/h in winter (speed limit signs were changed twice a year on main roads).

A study of Finnish weather-activated speed signage was undertaken by Rama (1999). A slippery road variable message sign was displayed in adverse weather conditions. This had the effect of further reducing the mean speeds of cars by 1.8 km/h on top of the reduction of 9.3 km/h due to the adverse weather.

Similarly, European Commission (n.d.) noted that in Sweden:

- On freeways/motorways, the speed limit was 110 km/h in summer and 90 km/h in winter.
- On rural roads where the summer speed limit was 90 km/h, it was reduced to 70 km/h in winter.

5.4 Summary

Many examples of jurisdictional guidelines for setting speed limits at higher-risk locations were identified in Australia, New Zealand, the USA and in European countries. The common factors that define higher-risk locations where a lower speed limit may be considered include:

- significant presence of vulnerable road users, especially pedestrians (e.g. near schools, in commercial and shopping areas, beach or park areas)
- crash rate or crash cost per kilometre of travel (individual risk)
- residential areas with a crash problem (supported by traffic calming)
- general presence of hazardous road and roadside engineering features, e.g. substandard curves, steep grades, roadside hazards, frequent intersections and direct access points

- high-speed at-grade intersection approaches
- roads with poor risk assessment scores
- weather or climatic conditions.

Road hierarchy was a significant consideration in the selection of speed limits, even at high-risk locations. Generally, the higher in the road hierarchy, the higher the speed limit.

6. Examples of Application of Lower Speed Limits on Higher-risk Roads

This section describes various speed zoning and speed management initiatives undertaken by different jurisdictions on higher-risk roads not amenable to cost-effective engineering treatments (road lengths, areas and intersections). Consultation was undertaken to gain further information on the implementation of reduced speed limits on higher-risk roads. To provide a broad range of existing practices, senior practitioners were contacted from most Australian and New Zealand jurisdictions, the United Kingdom, USA, the Netherlands, Sweden, and Germany.

This section details the types of speed reduction trials that have been implemented, with the examples arranged by the risk type being addressed.

6.1 Pedestrian Activity Areas

Road sections where the risk of injury is high due to the significant presence of pedestrians, cyclists and other vulnerable road users can be treated with time-based or permanently reduced speed limits. Typical examples of lower speed limits in pedestrian activity areas include the 40 km/h limits in shopping centres, school zones (time-based or permanent) and on residential access roads. For strip shopping centres and residential access roads, physical traffic calming treatments are sometimes used to support the lower speed limit.

Various special zones such as beach esplanades and car parks also may have lower speed limits applied to improve safety for cyclists and pedestrians. Some examples of speed limit reduction trials to reduce pedestrian crashes in Australia, New Zealand and the UK are provided in the following sections.

6.1.1 NSW High-volume Pedestrian Areas

RMS (formerly RTA) introduced 40 km/h speed limits as part of the High Pedestrian Activity Area (HPAA) scheme from 2002. The 40 km/h HPAA was installed on roads that already had traffic calming devices in place, or on roads that naturally restricted the vehicle speed (RTA 2005). There were 100 of these high pedestrian activity areas throughout NSW at the time of writing, predominantly in Sydney and other city centres such as Coffs Harbour, Newcastle and Wollongong (as advised by Yogen Bhatnagar of Roads and Maritime Services, November 2011).

6.1.2 Victorian Strip Shopping Centres and Melbourne CBD

In Victoria, 18 strip shopping centres were selected for application of lower speed limits based on their poor pedestrian crash history. Variable speed limits were installed at these strip shopping centres in 2005 to improve safety at the times of the highest pedestrian activity. An evaluation by Scully, Newstead and Corben (2008) concluded that the lower speed limits reduced casualty crashes by 8% and pedestrian casualty crashes by 17% (not statistically significant at $p \leq 0.05$).

A 40 km/h speed limit was introduced in the Melbourne CBD in October 2012 to reduce the risk and severity of pedestrian crashes. The reduced speed limit applied to all roads within the easily identifiable rectangular city grid, with the exception of roads and laneways with existing 30 km/h or 10 km/h speed limits. An evaluation of the effect on pedestrian crashes was yet to be carried out at the time of writing.

6.1.3 Brisbane CBD

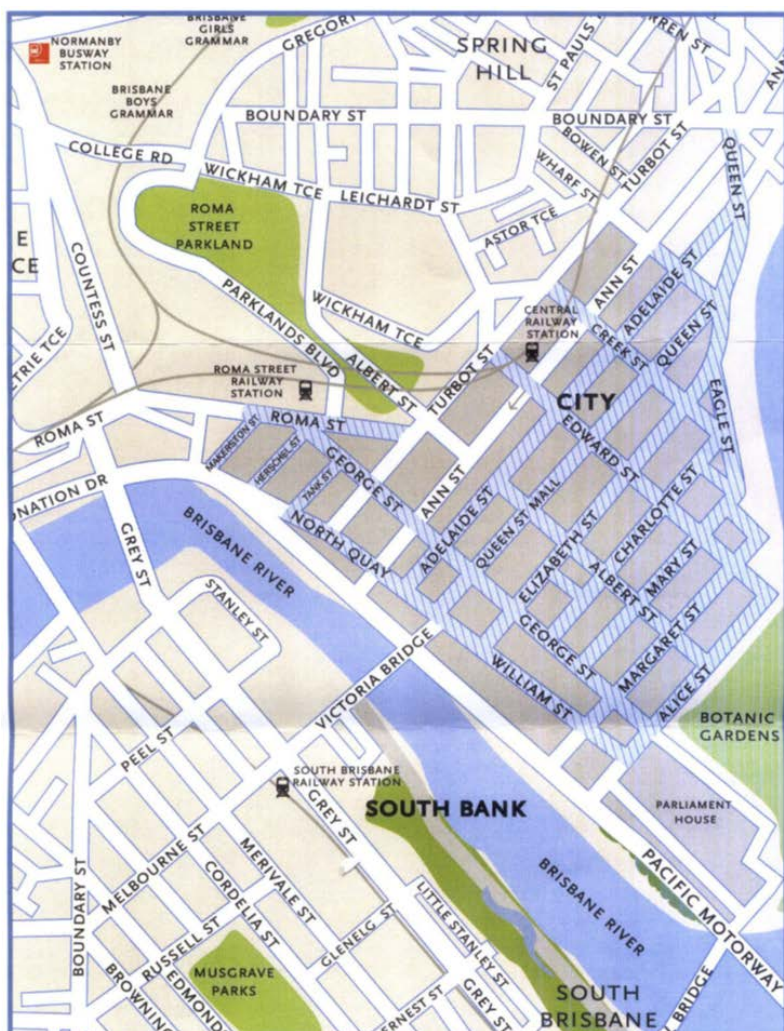
Following community consultation, Brisbane City Council reduced the speed limit within the Brisbane CBD from 50 km/h to 40 km/h in April 2009. The move was prompted by the significant crash history throughout the CBD, including a high number of pedestrian injuries between 2001 and 2006.

The reduced speed limit applied to the following streets in the CBD area:

- between Ann Street and Alice Street, including Alice Street
- between North Quay and Boundary Street, including North Quay
- George Street, including the section between Roma Street and Ann Street
- Roma Street, Tank Street, Herschel Street and Makerston Street.

The extent of the speed limit reduction is shown in Figure 6.1.

Figure 6.1: Brisbane CBD illustrating the extent of the 40 km/h speed limit (shaded area)



Source: Brisbane City Council (2009).

The 40 km/h speed limit did not apply to Turbot Street and Ann Street as these were considered key traffic-carrying routes.

No formal evaluation of the speed limit was available at the time of writing.

6.1.4 Perth CBD and Northbridge, WA

A permanent 40 km/h speed limit was implemented throughout the Perth CBD and Northbridge in June 2011. The new limit was introduced to improve safety for pedestrians and cyclists and potentially reduce crash rates, and follows the examples of other Australian cities. The change reflects the approach in the City Council's 20-year plan to prioritise people first, public transport second, and cars last in the CBD area. Figure 6.2 shows two entry points into the lower speed area. It was too early to evaluate the treatment at the time of writing.

Figure 6.2: Permanent 40 km/h speed limit area in Perth CBD



6.1.5 Perth Strip Shopping Centre – Beaufort Street, Mt Lawley, WA

Main Roads Western Australia is trialling a variable speed zone along a shopping centre precinct in Beaufort Street in the suburb of Mt Lawley in Perth. The section of Beaufort Street is an area of high pedestrian traffic with traffic volumes of 40 000 vehicles per day, and had a higher than average pedestrian crash rate for the metropolitan area. The trial began in August 2009 and aimed to improve safety for pedestrians and other road users by lowering travel speeds from 60 km/h to 40 km/h during peak periods of pedestrian activity.

Variable electronic speed signs were used to display the reduced limit of 40 km/h at the following times:

- Sunday to Thursday: 7.30 am–10.00 pm
- Friday and Saturday: 7.30 am–1.00 am.

Outside these times, the existing 60 km/h limit is displayed on the electronic signs.

According to Main Roads WA (2013), the trial was to be conducted for 18 months to allow the full impact of the works to be assessed with a post-treatment study. At the completion of the post-treatment study, an appropriate speed limit was to be implemented. Speed and crash results were not available at the time of writing.

6.1.6 Hobart, Tasmania

Selected roads close to the Hobart CBD had speed limits reduced from 60 km/h to 50 km/h in August 2011 (Hobart City Council n.d.). These roads were identified as higher-risk locations due to the high number of pedestrians and cyclists in the area, and the large number of residential and commercial vehicle accesses to urban arterial roads.

A speed limit of 30 km/h has been in place around the Elizabeth Street Mall in the Hobart CBD since 2008 (Tasmania Government 2008). This was introduced to improve safety for all road users, especially pedestrians.

No evaluations of these speed limit reductions were available at the time of writing.

6.1.7 Canberra Retail Areas, ACT

A 40 km/h speed limit trial to improve safety in busy town centres, in the retail areas of the Woden and Gungahlin in Canberra, was in progress during the project. The trial aimed to help improve safety for pedestrians, cyclists and other roads users in the ACT (ACT Government 2011). If the trial proves successful, the 40 km/h speed zones may be introduced in other shopping centre precincts in Canberra. Roads ACT have advised that the trial had not been evaluated at the time of writing.

6.1.8 Christchurch School Speed Zone Trial, New Zealand

One of the first trials of a part-time 40 km/h school speed zone was in Christchurch. The two-year trial began in January 2000, and included urban and rural areas with existing speed limits of between 50 km/h and 70 km/h. Electronic variable speed limit signs were used for the first time in New Zealand as part of this trial.

An analysis by the council showed a high level of support for the zone from the school community and general public; 92% of respondents in a survey replied that it was a good idea (Cottam 2001).

Although before-and-after speed surveys were not performed to determine the reduction in speeds, responses from a survey of local residents who frequently drove through the zone indicated that 81% claimed to drive at or below 40 km/h when the zone was active (Cottam 2001). A later evaluation by Osmer (2001) did measure speeds, and found a reduction in mean speeds to around 40 km/h, although only while children were present.

Other New Zealand examples of the application of lower speed limit guidelines aimed at higher-risk locations, detailed in Koorey (2011), are:

- extension of 40 km/h school speed zones to all major cities (Auckland, Wellington and Christchurch)
- introduction of a 30 km/h speed limit in the Hamilton CBD
- implementation of five 30 km/h speed zones in the Wellington CBD and suburban shopping street areas
- a trial of 50 km/h school zones in rural areas, around seven Selwyn District schools.

Koorey did not provide information regarding road safety evaluation of any of these lower speed limit examples.

6.1.9 City of Hull, UK

The City of Hull in England introduced a 20 mph (32 km/h) speed limit on a quarter of its local roads, which included residential streets and local distributor routes outside schools. Due to the high number of pedestrians and cyclists on these roads, and the comparatively high proportion of pedestrian fatalities being children, these were considered higher-risk locations. The City of Hull had a large proportion of commuters who walk or cycle to work (10% walk, 14% cycle) (Parliament UK 2002). The aim was to reduce pedestrian and cyclist casualties on local roads. Parliament UK (2002) implies that some traffic calming measures were used to support the 20 mph zones.

A simple before-and-after time series comparison indicated that the fatal and serious crashes dropped by 90%, and crashes involving child casualties dropped by 54%. The traffic growth was less than 1% per annum. The study method did not adjust the results for control sites, but the report noted that surrounding municipalities recorded casualty crash increases.

6.1.10 London, UK

A similar project, although on a much larger scale, was carried out by the City of London. A large-scale adoption of 20 mph (32 km/h) speed limits was carried out over the period spanning 1999 to 2007. The lower speed limit was supported by at least some traffic calming measures (no details provided). A well-planned time series modelling with control roads was carried out by Grundy et al. (2009) to assess the effectiveness of the lower speed limits.

The evaluation showed an estimated 42% reduction in casualties following implementation, after adjusting for overall crash trends in the area (statistically significant at $p \leq 0.05$). The number of child fatalities and serious injuries (combined) fell by 50% (statistically significant at $p \leq 0.05$). Pedestrian and motorcyclist casualties declined by a third and cyclist casualties by 17% (all statistically significant).

6.1.11 Camden High Street, UK

An 18-month speed limit trial was undertaken on Camden High Street in London. Camden High Street had a crash rate double that of other similar 'A' roads in the borough (Transport for London 2009). The trial involved reducing the speed limit by 10 mph (16 km/h), with traffic lights programmed to give a green light to vehicles travelling at or below the speed limit of 20 mph (32 km/h), and display a red light to speeding vehicles.

Transport for London was monitoring the trial and was to assess the impact of the reduced speed limit on the crash rate to determine if the limit was to remain at 20 mph (32 km/h) permanently. Results of the trial were not available at the time of writing.

6.1.12 Stockholm CBD, Sweden

A 30 km/h default speed limit on local and residential roads in Stockholm was introduced by the Stockholm City Council in 2007 (personal communication, Torsten Bergh, formerly of Swedish Transport Administration, 16 September 2011). An evaluation was not available at the time of writing.

6.2 Rural Roads

6.2.1 Rural Highways, Queensland

Edgar and Tripathi (2011) provided a preliminary evaluation of five examples of speed limit reductions on rural highways selected on the basis of significant crash history. In particular, an excessive crash rate for the given road type and traffic volume was one of the main criteria. Another selection criterion was that the road lengths could not be substantially treated with engineering measures in the short-term. The 'black links' selected for the speed limit reduction trial were located within the following highway sections:

- Bruce Highway (Cooroy – Gympie)
- Bruce Highway (Gympie – Maryborough)
- Bruce Highway (Innisfail – Cairns)
- Warrego Highway (Toowoomba – Dalby)
- Mount Lindesay Highway (Brisbane – Beaudesert).

The speed limits were reduced from 100 km/h to 90 km/h at the end of 2008. The reductions were accompanied by additional police enforcement. The speed zones were also reinforced by installation of large non-standard warning/advisory signs informing drivers of the reason for the speed limit reduction (e.g. head-on crashes) and of the increased enforcement. More frequent speed limit repeater signs were also installed along each route.

The follow-up evaluation showed that motorists' speeds fell noticeably. Across all sites, the 85th percentile speed dropped by 9 km/h and the mean speed by 8 km/h. The lower speeds were sustained over the 18 month monitoring period. The trial did not include a control group of roads; hence it was not possible to isolate the effect of the treatment from other influencing factors (e.g. overall changes in speed enforcement, annual rainfall, etc.). Therefore, the results should be treated as indicative only.

6.2.2 Adelaide Hills, South Australia

Following a state-wide review of speed limits undertaken by Transport SA in 2002, targeted speed limit reductions were introduced in the Adelaide Hills (Long & Hutchinson 2008). A total of 18 rural road sections had their speed limits reduced from 100 km/h to 80 km/h. The roads were characterised by varying horizontal and vertical curvature.

As part of the change in speed limit, 100 new signs were installed and the new speed limit was immediately enforced by police. Speed surveys were conducted six months before and after the speed limit change. Long and Hutchinson (2008) evaluated effectiveness of the speed limit change reporting that mean travelling speeds dropped by 2.5 km/h, the 85th percentile speeds by 4.3 km/h and 95th percentile speeds by 4.8 km/h. The authors also reported that there was an average 15% reduction in casualty crashes on the road sections where the speed limit was reduced (not statistically significant, $p > 0.05$).

6.2.3 Great Ocean Road, Victoria

A speed limit reduction from 100 km/h to 80 km/h was applied along an 80 km curving section of the Great Ocean Road, Victoria in 2004. The road is a major tourist route with frequent changes in horizontal and vertical alignment, narrow lane width and roadside hazards, which all contribute to increased crash risk. The road also had an increasing motorcycle crash problem.

Accompanying the change in speed limits, road infrastructure improvements were made, such as installation of sealed shoulders, guard fences and improved delineation. Motorcycle-friendly products (rub rail, aluminium posts) were also fitted. Police enforcement was increased over the trial section. During the trial, there were various lengths of roadworks, with associated speed limits of 40 km/h.

An unpublished VicRoads evaluation indicated a reduction in speeds of between 3 km/h and 12 km/h at the four sites assessed, and a 28% observed reduction in fatal and serious crashes (reported from personal communications in Jurewicz & Turner 2011). However, the reduction attributable to the change in speed limit is unclear, in light of the physical improvements to road infrastructure, increased enforcement during the trial, and lack of control sites.

6.2.4 Rural Roads in New Zealand

A speed limit reduction trial on two-lane undivided rural roads with varying horizontal and vertical alignment was undertaken in 2005–06 by Land Transport New Zealand (now the NZ Transport Agency). A mixture of risk assessment and the 85th percentile speed from speed surveys was used to identify potential locations for speed limit reductions. Speed limits were reduced at a number of sites, including from 100 km/h to 90 km/h, 80 km/h, 70 km/h, 60 km/h or 50 km/h, and one site where the speed limit was reduced from 70 km/h to 50 km/h.

The mean speed was generally below the speed limit before and after the changes in speed limit. Results from speed surveys indicated that the 85th percentile speeds reduced for every speed limit category; the reductions ranged between 0.8 and 9.0 km/h (Austroads 2010b). However, speeds reduced more at the control sites than the treatment sites.

As part of the same trial, a selection of roads was evaluated using a risk-based method for speed limit setting on rural roads (Edgar 2006). The draft speed zoning guidelines stated that the risk assessment was carried out for only short segments of the road section (10% or less) being reviewed (Land Transport NZ 2005). This limited the amount of effort required in the review. The risk rating process assigned numeric scores to risk factors depending on their design level and the risk to road users. The following variables were considered in the risk assessment:

- frontage development density
- presence of side roads
- speed change (variability) along the route
- seal width
- roadside hazards
- opposing traffic separation
- sight distance
- AADT and vehicle composition
- vulnerable users.

Edgar (2006) suggested that rural speed limit setting in New Zealand should be based on a combination of 85th percentile speeds and a risk-based calculation. This reflected both the speeds at which motorists wish to travel, as well as road-based risks, some of which motorists may not perceive. This approach set the speed limit conservatively, so that only the most 'antisocial' drivers were targeted. The actual level of risk for each road was calculated based on three groups of road features: an activity total, roadside crash potential and traffic crash potential. These features were used to create a speed zone rating score, which corresponded to an appropriate speed limit. The risk assessment outcome was used only as a consideration in the selection of the speed limit, which was otherwise set on the basis of the 85th percentile speed.

A guidance document has been prepared for the installation of rural speed zones, where speed limits were reduced on some sections of rural road where there was adverse road geometry.

6.2.5 Rural Roads in the Netherlands

The speed limit for minor rural roads was reduced from 80 km/h to 60 km/h on an area-wide basis in the Netherlands as part of the Sustainable Safety initiatives in 1998. These minor rural roads were generally two-lane undivided roads with traffic volumes up to 5000 vehicles per day, and included a wide mix of traffic including trucks, cars and vulnerable road users (cyclists and pedestrians). Many of these rural roads were of poor quality, with Wegman and Aarts (2006) reporting that the risk of road fatalities per million vehicle kilometres travelled on minor rural roads was 10 times that of motorways.

Low-cost engineering treatments were applied to 20 road lengths and intersections as part of the study. These included signage (zone-boards at the start of a speed zone), edge markings instead of centre lines, installation of painted bicycle lanes, and speed humps and speed tables at intersections and accesses (Figure 6.3).

A retrospective before-and-after analysis was carried out, with a total of 851 km of roads being treated with the speed limit, and compared to a control group of 2105 km of roads with a speed limit of 80 km/h.

The effect of the application of 60 km/h zones was summarised by Jaarsma et al. (2011). An initial evaluation of the trial showed a statistically significant effect on casualty crashes, with a reduction of 24% overall and a 44% reduction at intersections. However, these results may not have been indicative of all the sites and should be treated with caution.

Figure 6.3: Engineering treatments applied during the rural speed limit trial in the Netherlands



Source: Jaarsma et al. (2011).

6.3 Freeways/Motorways

Reduced speed limits on motorways and freeways are sometimes used to reduce congestion and frequency of crashes and minor incidents. Some examples in Australia, Europe and the UAE are provided below.

6.3.1 Managed Motorways Scheme in the UK

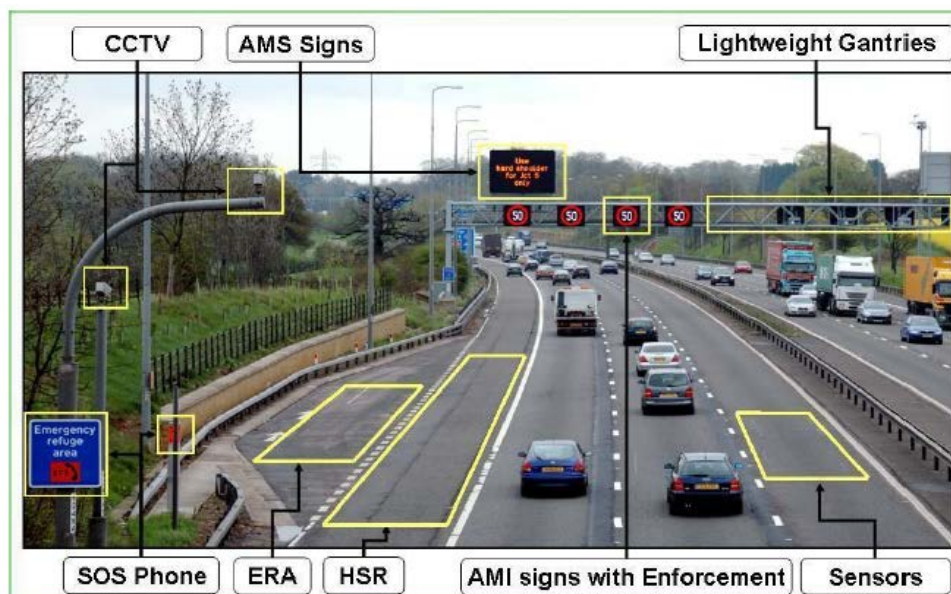
Reduced speed limits operate on motorways in the UK as part of managed motorways (MM) schemes developed by the Highways Agency UK. There were 35 schemes in operation nationwide in 2012 (Highways Agency 2012). A risk-based approach was used following the development of a risk profile based on expected hazards. Each was given a score based on likelihood and severity. Although the primary reason for introduction of the reduced speed limits via variable mandatory speed limits (VMSL) was to reduce congestion, a reduction in the incidence of crashes was also achieved.

VMSL technology is used to show the variable speed limits on the motorways, and additional messages such as 'queue ahead' or 'queue caution' are displayed. The VMSL signals are also used to control traffic around a collision or lane closure due to road maintenance works. This provides additional protection to the field workers and more advanced notice to road users. All signals are mandatory and enforceable.

A computer system was used to calculate the most appropriate speed limit based on the volume of traffic on the motorway ahead. Speed limits were then reduced dynamically in response to the current traffic conditions, often for periods of only a few minutes, thus reducing the risk of a collision at a particular time and location on the carriageway.

Hard shoulder running (HSR) was also part of the freeway management scheme. This involved the use of the hard shoulder as an extra traffic lane, thereby increasing the capacity of the motorway, and reducing congestion. Emergency refuge areas (ERAs) were provided for breakdowns or emergencies. Figure 6.4 shows the layout of the MM infrastructure including HSR.

Figure 6.4: Example of managed motorways scheme (the M42)



Source: Mott McDonald (2009).

Initially, a 50 mph (80 km/h) speed limit was applied during HSR operation. This was selected to mitigate the risk of collisions with any vehicles stopped on the hard shoulder (Highways Consultancy Group 2009). However, following an evaluation of a trial on the M42, the safety risk was deemed low, so 60 mph (96 km/h) was used throughout the network. There was a high level of compliance with the variable mandatory speed limits as part of the HSR system (Highways Consultancy Group 2009).

An initial evaluation was undertaken 12 months after the installation of the HSR scheme on the M42. Although the monitoring period was too short to give conclusive evidence, crash statistics showed that the average number of personal injury accidents reduced from 5.08 per month to 1.83 per month (Mott McDonald 2009).

6.3.2 120 km/h in United Arab Emirates (UAE)

Lower enforceable speed limits were introduced on two motorways in the UAE in 2011, the Abu Dhabi to Dubai motorway and the Dubai to Al Sweihan motorway. Previously, motorists did not trigger 'speed traps' (i.e. could not be fined) until reaching speeds of 160 km/h. The new official 120 km/h speed limit was applied with a 20 km/h tolerance, so motorists did not receive a fine unless travelling over 140 km/h. The new speed limits also assisted in decreasing the variability in speed between motorists, thereby improving safety.

At the time of writing, a full evaluation had not been undertaken. However, The National (2011) reported that four months after the speed limit reduction, the number of crashes had dropped by almost a third.

The Dubai to Al Sweihan motorway limit was applied in August 2011, so crash data was not yet analysed at the time of writing.

6.3.3 Variable Speed Limit Trial on the A7 Motorway in France

The A7 motorway is a three-lane dual-carriageway motorway in southern France. During the summer holiday period traffic volumes reached 110 000 vehicles per day. Reduced speed limits were trialled on a 90 km section, from Orange to Valence, during the summer of 2004. The trial was undertaken in order to reduce levels of congestion and the number of crashes (European Conference of Ministers of Transport 2006), and improve safety and comfort during periods of high traffic flow (Traffix Group 2009).

The intelligent transport system solution comprised sensors embedded in the road that measured the average speed over a minute period, the number of vehicles on the road, and the average gap between vehicles. Every six minutes, the speed limit was displayed as 70, 90 or 100 km/h depending on these measured traffic conditions.

Overhead gantries with variable message signs (VMS), located every 10 km were used to display the speed limits. Speed limits were also broadcast on a radio station every eight minutes. To encourage compliance, when the calculated speed was higher than the current mandatory limit on the section, the VMS displayed the vehicle's licence plate number and warned the driver to slow down (European Conference of Ministers of Transport 2006).

An initial evaluation showed 75% compliance with the variable speed limits. Evidence from roadside surveys indicated widespread support from motorists who generally encountered less congestion and fewer crashes during their journey (European Conference of Ministers of Transport 2006).

An evaluation of crashes over a one-month period in August 2004 showed a 48% reduction in all crashes and a 77% reduction in casualty crashes (Traffix Group 2009). However, this result was over such a short period that it should be treated with caution.

Following the success of the trial, the system was expanded along the A7. Traffix Group reported that another evaluation in 2007 showed a decrease in the total number of crashes by 20% over the three-year period.

6.3.4 Germany

Speed limit trials were undertaken on parts of German motorways that previously had no mandatory speed limit. European Transport Safety Council (2008) reported on two trials where a 130 km/h speed limit was applied, and a crash assessment was undertaken.

Introduction of a 130 km/h speed limit on a 167 km section of the A61 in Rheinland-Pfalz in 1991, combined with a ban on overtaking by heavy vehicles, resulted in a 30% reduction in fatal and severe injury crashes.

The introduction of a 130 km/h speed limit on a 62 km section of Autobahn 24, between Berlin and Hamburg in 2002, resulted in a 57% decrease in the number of casualties.

6.4 Adverse Weather Conditions

Adverse weather conditions increase the crash risk because of the reduced visibility (e.g. due to fog or heavy rain) and slippery road conditions caused by rain, ice or snow. When travelling at high speeds with reduced visibility, motorists have less time to react to a hazard on the road. Braking distance increases in wet condition, so lower speed limits can assist in increasing the time a motorist has to react to a situation, therefore reducing the number of incidents. Strong winds on some bridges can contribute to loss of vehicle control and run-off-road crashes.

Lower speed limits have been applied to roads that had an increased crash risk in adverse weather conditions in New South Wales. The following example is from a wet weather speed limit trial on the F3 Freeway.

The speed limit was reduced from 100 km/h to 90 km/h in wet conditions (de Roos & Wall 2006). The traffic volume on the F3 Freeway was approximately 40 000 vehicles per day. The section of the F3 Freeway was rated as having a high collective risk, and the percentage of crashes occurring in the rain was higher than expected. A large percentage of crashes in wet conditions had speed identified as a contributing factor.

Variable speed limit signs, weather stations, pavement moisture detectors, and static signs (Figure 6.5) were utilised in the trial. A fixed speed camera was placed at the site to enforce the 90 km/h wet and 100 km/h dry speed limits.

Figure 6.5: Static wet weather speed limit sign used in NSW speed limit trial



Source: de Roos and Wall (2006).

Initial results showed that compliance with the wet weather speed limit was excellent, with only 50 vehicles detected exceeding the limit over the first full month of operation of the trial (de Roos & Wall 2006). A crash analysis was not available at the time of writing.

The West Gate Bridge in Melbourne is often subjected to strong winds, and as a result, the speed limit can be reduced from 80 km/h down to as low as 40 km/h. Han, Pyta & Lennie (2008) reported on a study by Bean (2007), which indicated motorist acceptance, along with safety improvements due to the reduced speed limits.

Section 5.3.6 provides a number of other examples where guidelines or nationwide practice result in winter-time reductions in speed limits, e.g. in Sweden and Finland.

6.5 Intersections

Lowering the speed limit on the approach to intersections, especially in high-speed zones, can be used to encourage lower approach speeds, allowing more time for drivers to react and therefore reduce high-speed incidents.

Austrroads (2011b) reported that:

- Composite treatments, utilising a combination of various devices (such as vehicle activated signs, reduced speed limits, vertical and horizontal deflection) achieve reductions in speeds on the approach to rural intersections.
- Vehicle activated signs, particularly in association with reduced legal speed limits and other enhanced signing, assist in reducing approach speeds at rural intersections.

Examples of lower speed limits at intersections were found in Queensland and Tasmania. Tasmania applies lower speed limits at roundabouts and controlled intersections, while Queensland applies them at a variety of intersection types (Austrroads 2010b).

6.5.1 Queensland

Austrroads (2011b) analysed three cases where a reduced speed limit was the primary treatment on the approaches to intersections. The sites were selected on the basis of known crash history and a problem with inappropriate speed. The intersections were located on Warrego Highway, Bruce Highway, and Captain Cook Highway, all in rural locations and were sign-controlled. Pre-treatment and post-treatment speed data was available. The effectiveness of each trial was summarised in Austrroads (2011b) and is presented in Table 6.1.

The effect of lower speed limit on vehicle speeds could not be determined accurately as each trial site included additional treatments such as vehicle activated signs (VASs), enhanced signing¹⁰, and increased police enforcement during the 'after' period. However, the total combined treatments appeared to be effective in reducing 85th percentile speeds by up to 10 km/h (Austroads 2011b). The Bruce Highway site was the only one where post-treatment crash evaluation was available at the time of writing.

Table 6.1: Summary of safety outcomes of speed reduction trials at Queensland intersections

Trial location	Risks addressed	Treatment	Date	Effectiveness of trial – speeds and crashes
Rural intersection on Bruce Highway, Tandur Road intersection, 15 km south of Gympie	Crash history and vehicles travelling at inappropriate speed through intersection	Speed limit was reduced from 100 km/h to 80 km/h, high impact signs were installed showing reason for limit reduction, increased police enforcement in the follow-up period	June 2003	Decrease in mean speed of 7–8 km/h; 60% reduction in casualty crashes (4.5 years after installation)
Two intersections along Warrego Highway – Brisbane Valley Hwy and Lowood Minden Road (10 km north of Ipswich)	Crash history and vehicles travelling at inappropriate speed through intersection	Speed limit was reduced from 100 km/h to 80 km/h, installation of a VAS (displaying speed limit and 'slow down' message)	July/August 2009	Reduction in mean speed of 5–10 km/h
Rural intersection of Captain Cook Highway and Trinity Beach Road, north of Cairns	Crash history and vehicles travelling at inappropriate speed through intersection	A reduced speed limit of 60 km/h, warning signs and VAS were installed at a rural roundabout (Y-intersection configuration). VAS threshold was set at 82 km/h; 'slow down' message was displayed to vehicles exceeding this activation speed	July 2009	Decrease in 85 th percentile speed and mean speed. Decrease in overall number of speeding vehicles. Speed reductions maintained over 12-month evaluation period

Source: Austroads (2011b).

6.5.2 Europe

The Netherlands guidelines permit the establishment of a speed limit at intersections. At traffic lights on roads in rural areas, which are speed zoned at 80 km/h, the speed limit is reduced to 70 km/h. At higher-risk locations it can be reduced further to 60 km/h or 50 km/h.

In Sweden, at rural intersections where traffic volumes are above 1000 vehicles per day, electronic variable message signs are used in some instances to show reduced speed limits.

6.5.3 Speed Limits at Roundabouts

There are some examples of the application of lower speed limits with associated speed limit signage at roundabouts, in both urban and rural settings. For example, two new rural roundabouts in the Surf Coast Shire in Victoria have speed limit signage on the approaches.

Accident prediction modelling of the effect of speed limits on crashes at high-speed roundabouts was carried out by Turner, Wood & Roozenburg (2006), using a sample of 17 high-speed roundabouts in New Zealand. The model indicated that at roundabouts with speed limits of 80 km/h or greater, there were 35% more reported injury crashes than at roundabouts with an urban speed limit (50 km/h), for a given traffic volume.

¹⁰ Enhanced signing included the use of speed limit signs with fluoro backing boards or edges, signs with red backing boards, and large signs advising of increased crash risk.

6.6 Summary of Safety Outcomes of Speed Reduction Trials on Higher-risk Roads

A summary of crash reductions due to the various speed limit trials is presented in Table 6.2. Only locations where speed and/or crash data changes were evaluated are listed in the table. It is important to note that road infrastructure improvements and increased enforcement accompanied many of these projects.

Overall, Table 6.2 shows a reduction in observed crashes following speed limit reductions. However, the objective magnitude of safety improvements would be difficult to estimate. Many of the identified trials used methodologies that could not separate the effect of the speed limit reduction from other factors. Many trials included other treatments such as increased police enforcement and additional signage; and use of control groups was very limited. There has been a very limited evaluation of reduced intersection speed limits to date.

Section 11 discusses the key methodology for consideration in future trials of reduced speed limits.

Table 6.2: Summary of safety outcomes of speed limit reduction trials at higher-risk road sections

Trial location and type	Risks addressed	Initial speed limit (km/h)	Speed limit during trial (km/h)	Speed reduction (km/h)	% crash reduction
Pedestrian activity areas					
Victoria strip shopping centres – part-time application of 40 km/h speed limits	Crash history	60	40	n.a. ⁽¹⁾	8% casualty crashes 17% pedestrian casualty crashes Not statistically significant ⁽²⁾ (Scully, Newstead & Corben 2008)
City of Hull, UK – 20 mph (32 km/h) speed limits with traffic calming	Pedestrian and child casualties on local roads	48	32	n.a. ⁽¹⁾	90% fatal and serious injuries 54% child casualties Significance not tested (Parliament UK 2002)
London, UK – 20 mph speed limits with traffic calming	Road injuries, pedestrian and cyclist focus	48	32	n.a. ⁽¹⁾	42% road casualties 33% pedestrian casualties 50% child fatalities and serious injuries 17% cyclist casualties Statistically significant ⁽²⁾ (Grundy et al. 2009)
Rural roads					
Sections of Bruce Highway, Warrego Highway and Mount Lindesay Highway – speed limit reduction, signage improvements and increased enforcement	Casualty crashes	100	90	Mean speeds – 8 km/h 85th percentile speeds – 9 km/h	n.a.; significance not tested (Edgar & Tripathi 2011)
Adelaide Hills, South Australia – speed limit reduction	Adverse road alignment	100	80	Mean speeds – 2.5 km/h 85th percentile speeds – 4.3 km/h	15% casualty crashes not statistically significant ⁽²⁾
Great Ocean Road, Victoria – speed limit reduction, targeted infrastructure improvements and extra enforcement	Run-off-road crashes on curves, road alignment, hazardous roadside environment	100	80	Mean speeds – 3–12 km/h	28% fatal and serious injury crashes Significance not tested (reported from personal communications in Jurewicz & Turner 2011)

Trial location and type	Risks addressed	Initial speed limit (km/h)	Speed limit during trial (km/h)	Speed reduction (km/h)	% crash reduction
Rural roads in the Netherlands – area-based speed limit reductions plus low-cost engineering measures	High crash risk, wide variety of road users on rural roads	80	60	n.a. ⁽¹⁾	24% casualty crashes 44% Intersection casualty crashes Significance not tested (Jaarsma et al. 2011)
Freeways/motorways					
Abu Dhabi to Dubai motorway, UAE – speed limit reduction	Variability in speed between motorists	160	120	n.a. ⁽¹⁾	33% casualty crashes (four months after installation) Significance not tested (The National 2011)
A7 motorway, France – variable speed limits 70–100 km/h	High number of crashes and traffic congestion	100	90 or 70 (via VMS)	n.a. ⁽¹⁾	20% all crashes No information on significance testing (Trafix Group 2009)
A61 and A24, Germany – introduction of 130 km/h speed limit	Serious and fatal crash risk	None	130	n.a. ⁽¹⁾	30% A61 – fatal and serious injury crashes 57% A24 – casualty crashes No information on significance testing (European Transport Safety Council 2008)
Intersections					
Bruce Hwy/Tandur Rd, near Gympie, Queensland (sign-controlled) – speed limit reduction, signage improvements and increased enforcement	Intersection crashes	100	80	Mean speeds – 7–8 km/h	60% casualty crashes; significance not tested (Austroads 2011b)
Warrego Hwy, at Brisbane Valley Highway and at Lowood Minden Road, Queensland (sign-controlled) – speed limit reduction, VAS signage and increased enforcement	Intersection crashes	100	80	Mean speeds – 5–10 km/h	n.a.; significance not tested (Austroads 2011b)

1 n.a. – not available.

2 At $p \leq 0.05$.

The general conclusion from the evaluations of speed limit reductions on higher-risk roads and intersections in Table 6.2 is that speed limit reductions were frequently associated with mean speed reductions, and with reductions in casualty and severe crashes/injuries. It should be pointed out, however, that many speed limit reductions were accompanied by other interventions such as traffic calming, signage and increased speed limit enforcement. Thus, it is not possible to attribute the effects to the reduced speed limit reduction alone.

In the case of reduced intersection speed limits, the evidence for safety improvement was very limited. The results were also affected by additional treatments. This points to the need to carry out a robust study of the safety effects of reduced speed limits at intersections. Such a study could look at rural and urban intersections with different types of control (i.e. signs, signals and roundabouts).

7. Trial and Finalisation of the Model Guidelines

The project sought a trial application of the 2011–12 draft of the model guidelines in order to identify any areas needing refinement. The purpose of the trial was to test the data requirements and ease of application of the model guidelines.

The trial application was carried out in mid-2012 following nomination of 10 road lengths and three intersections by jurisdictions, along with submission of available supporting information. The trial application involved a desktop review of the provided information (crash rates, road user information, road features and speed information), site visits at selected locations, and selection of the proposed speed limit using the draft model guidelines. Observations and commentaries were recorded during the process.

Table 7.1 shows the results of the trial application of the draft model guidelines for road length, and Table 7.2 shows the results for intersections. The 'typical speed limit' column in Table 7.1 indicates the speed limit that would have been recommended using Table 5.4 of Austroads (2008b). In some cases, two alternative speed limits were listed, as the table did not provide enough clarity for the situation.

Table 7.1: Road lengths included in the trial and results

Road lengths	Category and function	Typical speed limit (km/h)	Existing speed limit (km/h)	Suggested speed limit (km/h)	High severe crash risk factors
Bulcock St, Caloundra, Queensland (0.6 km)	Urban local access/ collector road	40	40	40	Presence of pedestrians in high numbers.
Cooroy – Noosa Rd, Tewantin, Queensland (2.8 km)	Urban arterial road – undivided	60	60	60	No high risk factors (subject to severe crash rate check, data not available)
Abernethy Rd, Welshpool, WA (3.2 km)	Urban arterial road – divided	70/80	70	70	Higher access frequency and high-risk curves
Watsonia Rd, Maida Vale, WA (1.0 km)	Rural residential road	80	60	60	Note one 40 km/h school zone
Wilson Rd, Ilkey, Queensland (5.6 km)	Rural road – undivided	90/100	Unsigned default rural (100)	60	Winding and hilly alignment and $\leq 2\text{m}$ clear zone, low mean speed
Walhalla Rd near Walhalla, Victoria (9.2 km)	Rural road – undivided	100	Unsigned default rural (100)	60	Narrow lanes and winding alignment, motorcyclists, low mean speed
Korumburra-Warragul Rd near Warragul, Victoria (13.4 km)	Rural road – undivided	100	Unsigned default rural (100)	80	Curving alignment, no shoulders and high AADT
D'Aguilar Hwy (40A) near D'Aguilar, Queensland (8 km)	Rural road – undivided	100	100	80	High AADT and motorcyclist numbers
Warrego Hwy (18A) near Hatton Vale, Queensland (7 km)	Rural arterial road – divided	100	100	100	No high risk factors (subject to severe crash rate and AADT check, data not available)
Warrego Hwy (18A) near Hatton Vale, Queensland (6 km)	Rural freeway/motorway	110	100	100	Higher frequency of intersections and access points

Table 7.2: Intersections included in the trial and results

Intersection	Existing speed limit (km/h)	Proposed speed limit (km/h)	High severe crash risk factors
Princes Highway East/Sand Rd (stop sign)	100	80	Outer-metro arterial, high speed, high volume, at-grade, crash history, exceeds original rural function
Gympie Road/Beams Road (traffic signals)	70 south/80 north	Retain existing	Not a high-speed intersection, not really outer-metro, not intended as a rural intersection (traffic signals)
Beckmans Rd/Cooroy-Noosa Rd (stop sign)	80 west/60 east	Retain existing	Already low speed limits

Observations from the trial were presented to the reference group at the October 2012 workshop. The reference group considered a number of proposed refinements. The key conclusions from the workshop were:

- Model guidelines were quick and easy to apply, and did not require significant data inputs.
- The 40-60-80-100 approach made it easier to select a single speed limit for an entire road length under review.
- Simple high-crash-risk criteria reduced doubt in the selection of a speed limit. It was recommended not to set numeric values for high severe crash rates – this should be up to jurisdictions.
- Multiple high-risk factors resulted in a more, sound speed limit selection, even if one risk factor was not consistent throughout the entire road length. Multiple high-risk factors could be used to assign priority for implementation of a lower speed limit.
- It was possible to pre-select a speed limit from a site inspection without full data available (e.g. AADT, crashes, speed profiles), but it was recommended that full data be obtained because:
 - further speed limit reduction may be warranted in some cases, or
 - speed issues could be identified, which need action through speed management.

The workshop produced 14 amendments to the draft model guidelines. These were implemented in the final version presented in Section 8.

8. Model Guidelines for Setting Speed Limits at Higher-Risk Locations

These guidelines represent model practice and are not intended to replace the existing Austroads Guides. The model guidelines will be used in future reviews of such Guides. Section 10 provides a list of changes that may be considered in such reviews.

8.1 Background

The model guidelines aim to provide risk-based national speed limit guidance for different road categories/functions. The guidelines could be used to assess and implement reduced speed limits on higher-risk roads, intersections, and road lengths not amenable to short- to medium-term cost-effective engineering treatments. The guidelines may also help to identify a range of key factors contributing to the occurrence of severe crashes, and therefore suggest longer-term remedial treatments.

The model guidelines represent a harm reduction approach to speed limits, i.e. an achievable step towards the Safe System vision. Any speed limit reductions at higher-risk locations should be considered as short- to medium-term measures until major infrastructure upgrades can be justified.

The model guidelines build on the existing approach to setting speed limits, which recognises many of the same risk factors. The approach has been revised in light of the Safe System approach, new research evidence, and best practice presented in the earlier sections.

The format of the model guidelines will assist in more consistent application of speed limits and in limiting the frequency of speed limit changes.

8.2 Application of the Model Guidelines

The key intent of the model guidelines is to select speed limits based on the road category and function. Road lengths and intersections with a high risk of severe crashes should be recognised. Where engineering treatments have been either exhausted or are not cost-effective, a reduced speed limit may be considered as a short- to medium-term harm reduction measure.

These model guidelines recommend speed limit reductions for higher-risk road lengths and intersections. When major engineering improvements are implemented (e.g. redesign, realignment, or duplication), the reduced speed limits should be reviewed.

These model guidelines relate to permanent and time-based speed limits. They are not intended for the selection of variable speed limits based on dynamic algorithms on managed freeways, temporary speed limits for work zones or events, different vehicle classes, adverse weather or on floodways.

8.3 Recognition of Road Category and Function

The terms of reference for the model guidelines included recognition of different road categories and functions, and of crash risk levels in setting the speed limit. In this way, the model guidelines reconcile the level of road user protection offered by the road environment with the travel speeds acceptable to drivers.

The starting point for the speed limit selection was the typical speed limits in Australia based on Austroads (2008b). These speed limits are included as the starting-point speed limits in Table 8.2 and Table 8.3. They represent the speed limits often applicable on Australian roads, e.g. 60 km/h on urban undivided arterials, or 100 km/h on rural undivided roads. These speed limits represent the upper speed limits available if no high-risk factors are present.

The approach of recognising the road category and function means that the majority of the road network would retain current speed limits. Only those road lengths with significantly increased risk of severe crashes would attract reduced speed limits.

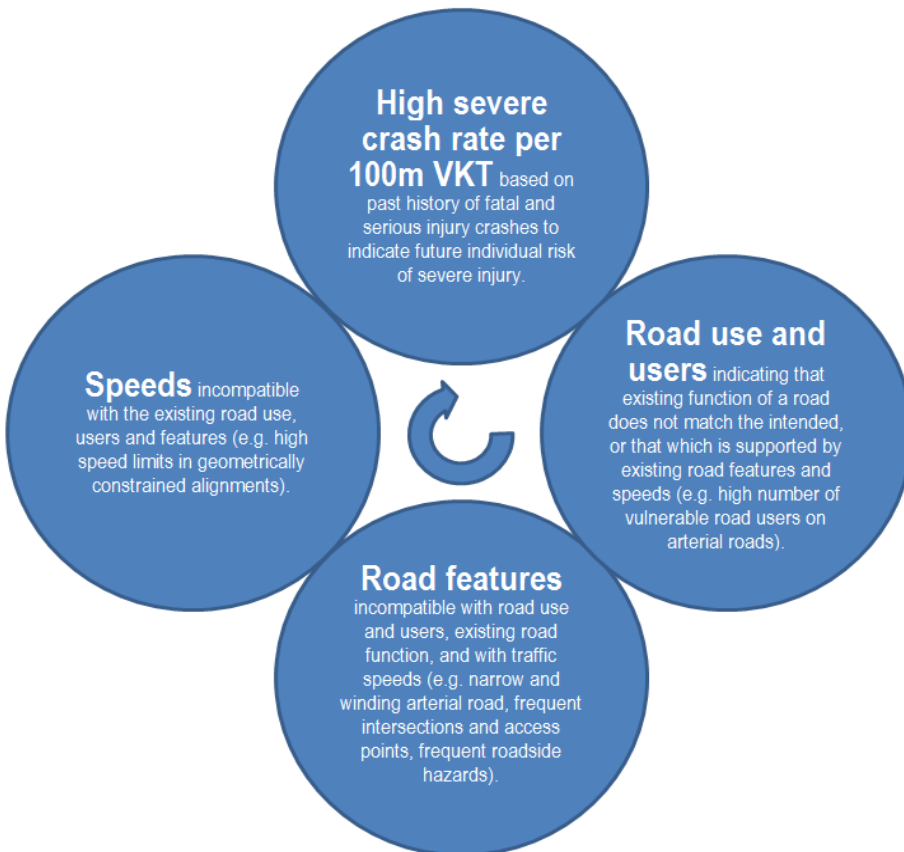
8.4 Key Factors Indicating Higher Risk of Severe Crashes

The findings of this project documented in previous sections suggest several ways of recognising higher-risk road lengths and intersections. Risk factors can be categorised into four groups. The presence of factors from any group may indicate high severe crash risk, as shown on Figure 8.1. Factors in three of these groups could be considered causal, i.e. influencing the main indicator of risk – the severe crash rate.

The risk factor groups closely follow the main pillars of the Safe System: Safe Roads, Safe Users and Safe Speeds. Safe Vehicles are also included, although indirectly, via road user factors.

The role of road category and function should be acknowledged in this relationship. Roads where the intended road function is poorly defined or unclear to road users due to existing road features, road use and speeds are likely to exhibit high crash rates.

Figure 8.1: Indicators of severe crash risk



High severe crash rates per 100 million VKT indicate individual risk of involvement in a crash and are based on historical crash records. The importance of severe crash rates as an indicator of higher risk has been discussed in Section 3.5.1.

Road use and user risk factors are also summarised in Section 4.2 in relation to vulnerable road users and vehicle numbers (collective risk). Roads with high numbers of pedestrians and cyclists were shown to have a higher likelihood of user-specific casualty crashes (severe crash results were not available). Some aspects of vehicle safety were also included by consideration of motorcyclist road use.

The research evidence relating to severe crash risk factors related to road features or infrastructure was summarised in Section 4.2. Appendix A provides a compendium of these severe crash risk factors arranged by urban/rural road environment. Appendix B provides the details of the literature reviews and analysis results. Rural and urban roads with features not adequate for the expected travel speeds are likely to exhibit high crash rates.

The Safe System speeds and the need for speeds to match the surrounding road infrastructure were discussed in Section 3.1 and Section 3.4. The risks and benefits of mean speed changes were described in Section 3.2. The additional casualty crash risk arising from a large speed variation from the mean speed was discussed in Section 3.3.

The model guidelines use detailed risk factors grouped under the headings in Figure 8.1 to identify higher-risk road lengths where speed limits could be reduced to improve safety. Specific crash risk factor categories were considered for inclusion in the model guidelines, if they more than doubled the severe crash risk. In selected scenarios, a combination of two or more factors was used to suggest a further reduction in speed limit.

There were a number of risk factors included in the model guidelines for which further evidence was desirable. Some were included in the guidelines on the basis of established speed zoning practice and stakeholder consensus, others on limited available research evidence. The factors requiring further research are discussed in Section 11.

8.5 Minimising Frequency of Speed Limit Changes

These model guidelines promote a route-based approach to speed zoning by focussing on speed limit setting and reviews of longer sections of road. This approach should result in more continuous speed limits.

Localised permanent speed limit reductions at individual hazardous locations (e.g. curves or black spots) should be avoided as they would challenge the credibility of speed limits and be difficult to enforce. They may also mask inherent road deficiencies that may be corrected as part of a forward capital works or maintenance program (e.g. road and roadside improvements, or delineation and signing). Localised speed limits at higher-risk intersections (Section 8.8), school and high pedestrian activity zones (typically 40 km/h) are exceptions to this approach.

Bridging of short gaps between the same existing speed limits is encouraged. Replacement of buffer zones with 'speed limit ahead' signs where there is no development is also encouraged by jurisdictional guidelines (e.g. Department of Transport and Main Roads 2011). These actions will help to ensure that speed limit changes address the prevailing crash risks along a given road section, whilst reducing the number of changes in speed limits along a route.

Following the project reference group input, the model guidelines suggest speed limits in multiples of 20 km/h, e.g. 20, 40, 60, 80 and 100 km/h, to reduce the number of small incremental speed limit changes. Some exceptions were retained to reflect widespread practice in many jurisdictions, e.g. 10 km/h shared zones, 70 km/h on some divided urban roads, or 110 km/h on rural freeways. Parts of this issue may be reviewed during the concurrent Austroads speed limit harmonisation project ST 1762, or by individual jurisdictions.

Table 8.1 proposes minimum lengths of speed zones for use with the model guidelines. The typical lengths are recommended for situations where a route or a road section has sufficient presence of the risk factor(s) described in Section 8.7, so that a reduction in the speed limit is warranted. The minimum lengths proposed in Table 8.1 are based on NSW practice and are longer than those in Standards Australia (2008). This practice was proposed to reduce the frequency of speed limit changes.

The localised speed limit reductions should be considered at:

- school zones
- pedestrian/cyclist activity zones (e.g. shopping strips)
- local residential areas
- rural hamlets and default speed limits through rural towns
- higher-risk intersections on outer-urban and semi-rural arterials as per the factors listed in Section 8.8
- at-grade rail crossings.

The reasons for lower localised speed limits over short lengths should be communicated to road users in these special cases to maximise their credibility (see Section 8.9). When there are several localised speed limit reductions next to each other (e.g. several school zones and shopping strips along one route), consideration should be given to consolidation of these into one continuous speed zone.

Table 8.1: Proposed minimum lengths of speed zones

Speed limit (km/h)	Minimum length of speed zone (km)	
	Typical	Localised
≤ 40	0.4	0.4 ⁽¹⁾
50 (default urban)	0.5	n.a.
60	1.0	n.a.
70	2.0	n.a.
80	2.0	0.8
100 (default rural)	3.0	n.a.
110	10.0	n.a.

1 Lower minimum speed zone lengths may be specified for specific applications such as school zones or pedestrian activity zones to suit local conditions, but should be no less than 200 m (absolute minimum).

Source: Based on Roads and Traffic Authority (2011).

8.6 Speed Limit Review Process

Austrroads guidance (2008a, 2008b) states that in the context of the Safe System approach, a range of factors including crash rates, operating performance, roadside infrastructure and geometry must be considered in the speed limit review process.

The existing speed limit review process described in Table 5.3 of Austrroads (2008b) has been revised in these model guidelines. The revision relates mainly to the order and simplification of the steps. It reflects the information needs of the proposed principles in Section 8.7, as follows:

1. Identify the need – the existing speed limit is not appropriate (e.g. due to development, change of function), existing safety issues cannot be addressed by engineering solutions; identify the road length/intersection.
2. Conduct traffic surveys – collect traffic volumes.
3. Calculate crash rates – fatal and serious injury crashes per 100 million VKT, crashes per kilometre (section limits and length, crash data and traffic volumes are required).
4. Conduct site investigations – visit the road lengths and intersections, document the data and observations as indicated in Table 8.2 and Table 8.3 for road lengths, or Section 8.8 for intersections.
5. Review all data and propose the preferred speed limit – refer to typical speed limits on roads of different categories and functions and to reduced speed limits at higher-risk lengths of these roads (Table 8.2 and Table 8.3). For reduced speed limits at higher-risk intersections refer to Section 8.8.

6. Stakeholder consultation – report and discuss the proposed speed limit with relevant stakeholders (e.g. state/local government, police, the party with authority for formal approval of speed limit changes).
7. Conduct second site investigation – review information, identify new/replacement sign locations, consider any works required to implement the speed limit change.
8. Approval – seek formal approval from the authorised party, document the process.
9. Inform stakeholders of the speed limit change, including the public.
10. Post-implementation check – check if the signs have been erected correctly, note any additional works to be done.

The proposed process applies to the road lengths and localised intersection speed limit reviews.

8.7 Selection of a Risk-based Speed Limit

Table 8.2 and Table 8.3 are the main references for the review and selection of speed limits on road lengths in the model guidelines. This includes localised reductions due to school zones and pedestrian activity zones.

As discussed in Section 8.4, each of the risk factors in Table 8.2 and Table 8.3 is considered to pose a high risk of severe crashes to road users, typically at least double the average risk level.

The table should be used in the following manner:

1. Identify the road category and its intended function (the left-hand-side column).
2. Note the typical speed limit. This is the upper limit that can be selected¹¹.
3. Work through the relevant row across each risk factor group, from left to right. Typically, a consistent presence of only one risk factor along the road length is sufficient to reduce the speed limit to the recommended value.
4. Note if any additional risk factors are present. Typically, the presence of multiple risk factors does not require further speed limit reductions, unless stated so.
5. The lowest recommended speed limit for a given road category should be considered for adoption. Self-explaining, low-cost treatments may be necessary to inform road users of the reason for a localised speed limit reduction.

The risk factor that is selected as the main reason for the speed limit reduction should occur frequently along the majority of the road length under review. If the risk factor occurs in a segmented fashion or infrequently (e.g. inadequate clear zone width), then the boundaries of the speed limit review should be revised. It is possible that warning signs or other engineering means are more appropriate than a speed limit reduction as a short- to medium-term solution. The same would apply if the risk factor was concentrated along only one segment of the road length under review, and the segment was shorter than the minimum speed zone in Table 8.1. In some cases, average values of the risk factor along the whole road length are used, e.g. access and intersection density.

For each speed limit review, it is important to gather information and assess all potential risk factors listed for the relevant road class and function. Documenting these risk factor assessments will ensure that the rationale for the speed limit reduction (or none) is defensible, e.g. in case of a legal challenge. Also, future speed limit reviews can use this information to monitor risk changes (e.g. due to gradual upgrades of the road features) and may lead to eventual reinstatement of the original speed limit.

¹¹ Some differences exist for rural roads in Western Australia and Northern Territory where the rural speed limits are 110 km/h and 130 km/h, respectively.

The presence of multiple severe crash risk factors does not generally result in a reduced speed limit (with some exceptions noted in the tables). Instead, the presence of multiple high-risk factors should highlight the relative priority for speed limit reduction.

The risk factor triggers in Table 8.2 and Table 8.3 may be reviewed and updated as part of a future review of Austroads guidelines.

The discussion in Section 11 identifies several factors included in the model guidelines for which further research is considered necessary.

Table 8.2: Urban roads – risk-based selection of speed limits for different road categories and functions

Road category/function and proposed speed limit (km/h)		Consider a reduced speed limit when any one of these severe crash risks is present ⁽¹⁾			
		Severe crash rate/100 million VKT	Road use and users	Road features	Speeds ⁽⁷⁾
Shared zones (fully built-up areas)	10	–	–	–	–
Car parks	20	–	–	–	–
Recreational areas/parks/reserves, large car parks	30	–	–	–	–
Urban local access and collector roads (fully and partially built-up areas)	50	–	–	–	–
	40	<ul style="list-style-type: none"> ▪ Pedestrian and cyclist severe crash rates are high⁽²⁾ 	<ul style="list-style-type: none"> ▪ Pedestrians or cyclists present in high numbers⁽²⁾, especially in commercial areas⁽³⁾ ▪ School frontage⁽³⁾ 	–	<ul style="list-style-type: none"> ▪ Mean speed is well below the existing speed limit⁽⁶⁾ due to traffic calming or geometric design of the road leading to high speed variation
Urban arterial roads – undivided (fully and partially built-up areas)	60	–	–	–	–
	40	<ul style="list-style-type: none"> ▪ Pedestrian and cyclist severe crash rates are high⁽²⁾ 	<ul style="list-style-type: none"> ▪ Pedestrians or cyclists present in high numbers⁽²⁾, especially in commercial areas and business districts⁽³⁾ ▪ School zone⁽³⁾ ▪ Two-way AADT, e.g. over approximately 48 000 vpd⁽⁹⁾ 	<ul style="list-style-type: none"> ▪ Rural town centres with commercial land use 	<ul style="list-style-type: none"> ▪ Mean speed is well below the existing speed limit⁽⁶⁾ due to congestion⁽³⁾, competing road uses⁽³⁾⁽⁴⁾, traffic calming or geometric design leading to high speed variation

Road category/function and proposed speed limit (km/h)		Consider a reduced speed limit when any one of these severe crash risks is present ⁽¹⁾			
		Severe crash rate/100 million VKT	Road use and users	Road features	Speeds ⁽⁷⁾
Urban arterials – divided (fully and partially built-up areas)	80	–	–	–	–
	70 ⁽¹⁰⁾	–	–	<ul style="list-style-type: none"> ▪ 2–4 standard access points per 100 m (includes intersections)⁽⁶⁾ ▪ Consistent and frequent presence of unprotected roadside hazards within 1.5 m of the traffic (e.g. trees/poles spaced closer than every 10 m, or continuous⁽¹¹⁾) ▪ No protection for left or right-turning vehicles ▪ Generally curving or winding road alignment (e.g. > 4 higher-risk curves per km ⁽⁵⁾⁽¹²⁾) 	<ul style="list-style-type: none"> ▪ Mean speed is well below the existing speed limit⁽⁸⁾ due to congestion⁽³⁾ and competing road uses⁽³⁾⁽⁴⁾ leading to high speed variation
	60	<ul style="list-style-type: none"> ▪ Severe crash rate is high⁽²⁾ 	<ul style="list-style-type: none"> ▪ Pedestrians or cyclists are present in high numbers⁽²⁾, especially in commercial areas and business districts ▪ On-road parking is permitted and occurs frequently along the route ▪ High one-way AADT, e.g. over approximately 56 000 vpd per carriageway⁽⁹⁾ 	<ul style="list-style-type: none"> ▪ > 4 standard access points per 100 m (includes intersections)⁽⁶⁾. More than two of the road feature risk factors for 70 km/h 	<ul style="list-style-type: none"> ▪ Mean speed is well below the existing speed limit⁽⁸⁾ due to congestion⁽³⁾ and competing road uses⁽³⁾⁽⁴⁾ leading to high speed variation
	40	–	<ul style="list-style-type: none"> ▪ School frontage⁽³⁾ 	–	–
Urban freeways/motorways (generally in fully and partially built-up areas)	100	–	–	–	–
	80	<ul style="list-style-type: none"> ▪ Severe crash rate is high⁽²⁾ 	<ul style="list-style-type: none"> ▪ High one-way AADT, e.g. over approximately 88 000 vpd per carriageway⁽⁹⁾ 	<ul style="list-style-type: none"> ▪ Sight distance consistently restricted ▪ Closely spaced interchanges where entry ramps and exit ramps are in close proximity, and there is frequent and conflicting merging and diverging activity 	<ul style="list-style-type: none"> ▪ Mean speed is well below the existing speed limit⁽⁸⁾ due to congestion⁽³⁾ leading to high speed variation

- 1 Any one of the points is sufficient to trigger consideration of a lower speed limit, unless specified otherwise.
- 2 High when compared with a state/regional average for the given road type. The values could be developed and maintained by each jurisdiction.
- 3 Lower speed limit may be applied part-time during high activity times.
- 4 Competing road uses would include such factors as frequent manoeuvres, e.g. deliveries, access/egress, frequent public transport activity and high turn-over parking.
- 5 Higher-risk curves may be considered those with a radius ≤ 600 m, or advisory speed significantly lower than the speed limit. There was no specific evidence of this risk factor for urban divided roads and the suggested value should be reviewed in the future.
- 6 Appendix D provides the method and weightings used in assessment of access and intersection density.
- 7 In many jurisdictions, mean speeds are close to the speed limit, subject to the effectiveness of the general deterrent of speed limit enforcement. Enforcement and other speed management techniques should be considered where mean speeds are substantially above the speed limit. Refer to Section 8.10 for a further discussion on this subject.
- 8 Mean speed may be already low in response to road engineering and operational factors (e.g. 10 km/h below the speed limit). In such cases, the speed limit may result in high speed variation, and/or provide an unreasonable target speed for some drivers. Reduction of the speed limit on the basis of low observed mean speed should be considered carefully.
- 9 High traffic volumes can result in high exposure to other risk factors and in higher severe crash numbers, unless crash risk is reduced in other ways (e.g. upgrade of road stereotype, or reduced access).
- 10 Some road agencies were in the process of rationalising the speed limits, e.g. focussing on removal of 70 km/h and 90 km/h limits. This idea was generally adopted in these model guidelines. This exception was made as most of the reference group agreed that this was a well-recognised reduced speed limit on lower quality divided urban arterials. If required by jurisdictional speed zoning policy, the roads meeting criteria for 70 km/h may be speed-limited to 60 km/h.
- 11 There was no research identified on what frequency of roadside hazards constitutes a substantially higher risk of severe crashes on urban arterials. The value was provided as an example. It was derived from road network observations and project team consensus. It should be reviewed when more robust research becomes available.
- 12 Previous Austroads research showed that casualty crash risk increases significantly when curves are combined with steep grade (typically $> 8\%$). If this is a relatively frequent occurrence for the road length under review, then a further reduction in speed limit may be considered, if practicable.

Table 8.3: Rural roads – risk-based selection of speed limits for different road categories and functions

Road category and function, upper speed limit (km/h)		Consider a reduced speed limit when any one of these severe crash risks is present ⁽¹⁾			
		Severe crash rate/100 million VKT	Road use and users	Road features	Speeds ⁽⁹⁾
Rural residential roads (partially built-up areas) ⁽⁵⁾	60	–	–	–	–
	40	–	<ul style="list-style-type: none"> School frontage⁽³⁾ 	–	<ul style="list-style-type: none"> Mean speed is well below the existing speed limit⁽⁹⁾ due to traffic calming or geometric design of the road leading to high speed variation
Rural roads – undivided (arterial and local; farmland, undeveloped, sparsely built-up areas)	100	–	–	–	–
	80	<ul style="list-style-type: none"> Severe crash rate is high, provided minimum AADT is exceeded⁽⁴⁾ 	<ul style="list-style-type: none"> High AADT⁽¹⁰⁾, e.g. over approximately 12 000 vpd 	<ul style="list-style-type: none"> At least two of: <ul style="list-style-type: none"> lane width ≤ 3.0 m ≤ 0.5 m sealed shoulders and effective unsealed shoulders < 1 m ≤ 2 m clear zone, or 2–4 m clear zone with high density/continuous roadside hazards generally curving and/or undulating road alignment (e.g. 2–4 higher-risk curves per km ⁽⁷⁾⁽¹¹⁾) 1–2 standard access points per 100 m (includes intersections)⁽⁸⁾ A rural hamlet/settlement 	<ul style="list-style-type: none"> Mean speed is well below the existing speed limit⁽⁹⁾ due to geometric design of the road

Road category and function, upper speed limit (km/h)		Consider a reduced speed limit when any one of these severe crash risks is present ⁽¹⁾			
		Severe crash rate/100 million VKT	Road use and users	Road features	Speeds ⁽⁹⁾
Rural roads – undivided (arterial and local; farmland, undeveloped, sparsely built-up areas) (cont.)	60	–	–	<ul style="list-style-type: none"> ▪ As per 80 km/h, but with the last two points being: <ul style="list-style-type: none"> - generally winding and/or hilly road alignment (e.g. > 4 higher-risk curves per km⁽⁶⁾) - > 2 standard access points per 100 m (includes intersections)⁽⁷⁾ 	<ul style="list-style-type: none"> ▪ Mean speed is well below the existing speed limit⁽⁹⁾ due to geometric design of the road
	100	–	–	–	–
Rural arterial roads – divided (farmland, undeveloped, sparsely built-up areas)	80	<ul style="list-style-type: none"> ▪ Severe crash rate is high⁽²⁾ 	–	<ul style="list-style-type: none"> ▪ At least two of: <ul style="list-style-type: none"> - ≤ 0.5 m sealed shoulders and effective unsealed shoulders < 1 m - ≤ 2 m clear zones, or 2–4 m clear zone with high density/continuous roadside hazards - generally curving and/or undulating road alignment (e.g. 2–4 higher-risk curves per km⁽⁶⁾⁽¹¹⁾) - 1–2 standard access points per 100 m (includes intersections)⁽⁷⁾ - sight distance consistently restricted ▪ A rural hamlet/settlement 	–
	100	–	–	–	–
Rural unsealed roads (no permanent seal or narrow seal ≤ 5 m wide; farmland, undeveloped, sparsely built-up areas)	60	<ul style="list-style-type: none"> ▪ Severe crash rate is high⁽²⁾ 	–	<ul style="list-style-type: none"> ▪ A rural hamlet/settlement 	–
	100	–	–	–	–

Road category and function, upper speed limit (km/h)		Consider a reduced speed limit when any one of these severe crash risks is present ⁽¹⁾			
		Severe crash rate/100 million VKT	Road use and users	Road features	Speeds ⁽⁹⁾
Rural freeways / motorways (farmland, undeveloped, sparsely built-up areas) and major roads in remote areas	110	-	-	-	-
	100	<ul style="list-style-type: none"> ▪ High severe crash rate⁽²⁾ 	<ul style="list-style-type: none"> ▪ High one-way AADT⁽¹⁰⁾, e.g. over approximately > 12 000 vpd per carriageway 	<ul style="list-style-type: none"> ▪ Sections with at-grade intersections less than 1 km apart⁽¹²⁾ ▪ Direct access > 2 standard access points per km ▪ Clear zones < 4 m 	-
	80	-	-	<ul style="list-style-type: none"> ▪ Sight distance is consistently restricted ▪ Adverse horizontal and/or vertical alignment AND consistent clear zone < 4 m ▪ A rural hamlet/settlement 	-

- 1 Any one of the conditions is sufficient to trigger a lower speed limit, unless specified otherwise.
- 2 High when compared with a state/regional average for the given road type. The values could be developed and maintained by each jurisdiction.
- 3 Lower speed limit may be applied part-time during high activity times.
- 4 The minimum AADT should be determined for each jurisdiction. Crash rates per 100 million VKT are typically high on low-volume roads but may be based on very few crashes (e.g. up to ~1000 vpd for rural undivided roads). The model guidelines are not intended to result in mass speed limit reductions on lower order roads which carry low traffic volumes. A high crash rate at a typical AADT for a given road stereotype would indicate a significantly increased individual and collective risk.
- 5 Refers to local roads that have partially built-up residential development, typically 2–4 standard driveways per 100 m. The abutting land holdings should be in excess of one acre.
- 6 Higher-risk curves may be considered those with a radius ≤ 600 m, or advisory speed significantly lower than the speed limit.
- 7 Appendix D provides the method and weightings used in assessment of access and intersection density.
- 8 In many jurisdictions mean speeds are close to the speed limit, subject to the effectiveness of the general deterrent of speed limit enforcement. Enforcement and other speed management techniques should be considered where mean speeds are substantially above the speed limit. Refer to Section 8.10 for further discussion on this subject.
- 9 Mean speeds may be already low in response to road engineering and operational factors (e.g. 10 km/h below the speed limit). In such cases, the speed limit may provide an unreasonable target speed for some drivers. No robust research evidence was available on the role of speed variation or speed targeting on crash risk on rural roads. Reduction of the speed limit on the basis of low observed mean speed should be considered carefully.
- 10 High traffic volumes can result in high exposure to other risk factors and in higher severe crash numbers, unless crash risk is reduced in other ways (e.g. upgrade of road stereotype, or reduced access).
- 11 Previous Austroads research showed that casualty crash risk increases significantly when frequent curves are combined with steep grade (typically > 8%). If this is a relatively frequent occurrence for the road length under review, then a further reduction in speed limit may be considered, if practicable.
- 12 On rural freeways, at-grade intersection refers to a highway standard design (or less) and does not include interchanges or other on/off ramps. Ramps are to be counted as access points.

While the project scope did not call for consideration of speed limit areas, the reference group input suggested that this aspect of speed limit setting should be an option in future guidelines. A road network area consistently exhibiting higher-risk factors could be considered for a reduced speed limit. Examples of such approaches were noted in Section 6.1 and Section 6.2, and included local neighbourhood areas and city business precincts.

8.8 Localised Speed Limit Reductions at Higher-risk Intersections

Safety at intersections that have design and operational deficiencies should be managed through relevant engineering treatments, including ITS solutions. Urban roads with frequent intersections should be considered for a reduction in the speed limit along the entire relevant road section.

Based on jurisdictional consensus, these model guidelines provide general guidance on the reduction of speed limits along major road approaches that meet the following higher-risk criteria:

- located on outer-metro, semi-rural and rural arterials
- have high volumes of traffic
- have high speed limits (> 80 km/h)
- are at-grade, sign or signal controlled
- experienced at least one of the following
 - significant increase in crashes due to growth in traffic volumes
 - permanent increase in complexity of traffic movements
 - permanent change in the surrounding road environment over a period of time (e.g. increased direct access)
 - current function of the intersection exceeds its original rural function, but an upgrade would not be cost-effective in the short- to medium-term.

Localised reduction of speeds at rural at-grade rail crossings may be also considered.

A reduced speed limit should be treated as temporary until funds can be made available to upgrade the intersection to match its current or desired future function. Safety and operational performance of an intersection with a reduced speed limit should be periodically monitored (e.g. annually).

Localised speed limit reductions at intersections should be signed using 60 km/h and 80 km/h speed limits unless local conditions suggest otherwise. The reduced speed limit signs should be accompanied by advisory signage, supplementary plates and increased enforcement to promote credibility of these short speed zones.

Generally, it is expected that the speed limit at intersection approaches would be returned back to the higher limit some distance past the intersection. If a lower speed limit already applies past the intersection, an effort should be made to create a continuous speed zone. This approach will lessen the impact of localised speed limit reductions on the frequency of speed limit changes.

Side-road approaches can be considered for speed limit reduction only in cases where their priority is comparable to that of the major road. The road agency responsible for the minor road may use other engineering means to reduce approach speeds on minor-road approaches to the intersection.

It is noted that the safety effects of localised speed limit reductions at intersections have had very limited evaluation to date. There was no robust evidence supporting lasting intersection safety improvements from reduced speed limits. Section 11 provides a discussion of the research needs in this area. Guidance on localised speed limit reductions should be revised once robust evidence has been developed.

8.9 Signing of Speed Limits

A speed limit is defined as the maximum speed at which a vehicle is legally allowed to travel on a particular section of road. A speed zone is defined as the length of road or a network of roads (i.e. area) within which a single speed limit applies.

Speed zones must be signed in accordance with the requirements of the applicable regulations in order for the zone to be enforceable. Specific details are contained in the Australian Road Rules: Part 3, AS 1742.4-2008 (Standards Australia 2008) and in jurisdictional speed zoning guide supplements¹².

Where the speed limit exceeds the maximum safe speed of travel at a particular isolated location, relevant warning signs, supplemented by advisory speed signs, should be used to advise drivers of the need to reduce speed.

It is recommended to retain references to the Austroads (2008b) Guide and relevant jurisdictional supplements on most speed limit signing matters. There are a number of existing examples of supplementary or dedicated signs developed for localised speed limit reductions, such as school zones or high pedestrian activity zones.

Nevertheless, the reference group considered that reduced speed limits on higher-risk roads and intersections should be clearly communicated to drivers. Such applications are not covered by current standards. A number of possible solutions were provided by the reference group for consideration in future practices.

Supplementary plates under speed limit signs could be used to explain the purpose of the speed limit reduction (e.g. high risk, crash zone, or similar). Such plates would need to be developed and specifically regulated for use with speed limit signs. An existing example is illustrated in Figure 8.2, where speed limits were reduced over an extended period due to freeway upgrade works. For consistency, the guidelines for use of such signs would need to be standardised across Australia, e.g. through Australian standards.

Figure 8.2: Regulatory speed limit sign with a supplementary plate



Alternatively, 'speed limit ahead' instruction signs could be considered with additional supplementary plates advising of the purpose of the reduction. A hypothetical combination is shown in Figure 8.3. Development of such signs would need to be checked against best practice in sign design.

¹² In New Zealand, this guidance is provided by the *Manual of traffic signs and markings (MOTSAM) – Part 1: traffic signs* (New Zealand Transport Agency 2010).

Figure 8.3: A potential design of a speed limit ahead sign with a supplementary plate



Another suggested solution could be the use of dedicated warning signs in advance of a speed limit reduction due to a higher crash risk. Figure 8.4 shows a draft design of such a sign.

Figure 8.4: A proposed warning sign ahead of a speed limit reduction



Source: Based on personal communication, Clint Cooper, Main Roads Western Australia, 27 January 2013.

These possible solutions may inform future discussions of Austroads Guides and Australian Standards revisions.

8.10 Speed Management

Speed management is a key element in ensuring that speeds are appropriately lowered in order to reduce crash risk. In the context of the Safe System approach, speed management should be applied in order to minimise serious harm to road users.

Austroads guidance (2008a, 2008b) states that effective speed management requires:

- appropriate infrastructure, through the use of
 - threshold treatments (e.g. road narrowing, traffic islands)
 - speed constraining treatments on lower speed roads (e.g. speed cushions, roundabouts, slow points)
 - perception treatments (use of trees/shrubs and road markings to alter streetscape)
- education – the community should be engaged and consulted on the benefits of appropriate speed limits
- enforcement of all speed limits by police.

Revision of speed management techniques was not part of this project's scope. A forthcoming report for Austroads project ST1426 and the concurrent Austroads project ST1768 focus on speed management techniques on rural and urban roads. Where speed limits of 40 km/h or lower are proposed, they should be accompanied by appropriate geometric design or traffic calming devices. Austroads (2008c) provides guidance on the use of traffic calming to encourage lower and more consistent speeds along local urban roads. Jurewicz (2009) provides further techniques and a practitioner toolkit for achieving the desired operating speed along an urban road. Effective traffic calming can also create conditions for safer and more comfortable cycling and walking. Substantial community involvement to identify, plan and design traffic calming is an essential part of this process.

Austroads (2009b) provides further details on speed management in activity centres, and the necessity for a low-speed traffic environment in areas of high pedestrian activity.

9. Dissemination Plan

The project sought to also propose a brief dissemination plan to facilitate the early consideration of the model guidelines at the national level. A consensus was reached during the project that the most effective way of achieving this objective was through future reviews of the Austroads *Guide to Traffic Management – Part 5* (Austroads 2008b) and *Guide to Road Safety – Part 3* (Austroads 2008a), as suggested in Section 10.

The following dissemination actions are proposed to facilitate consideration of the project findings in the Austroads Guide reviews:

- a PowerPoint presentation to be provided to Austroads and distributed to jurisdictions for internal dissemination presentations
- distribution of the final report free of charge to all project stakeholders, noting Section 10 relating to potential changes to the relevant Guides
- presentation of papers relating to the model guidelines at conferences, e.g. Australasian Road Safety Research, Policing and Education Conference
- authors participating in future Austroads Guide reviews
- authors providing advice to jurisdictions.

During 2012–13, Standards Australia was formally advised of the project and its preliminary findings. It outlined possible impacts on the speed limit selection process contained in AS 1742.4-2008.

10. Potential Changes to Austroads Guides

Part of the project scope was to identify the potential changes to the *Guide to Traffic Management – Part 5: Road Management* (Austroads 2008b Section 5). A discussion and a number of suggestions are provided in the following sections.

10.1 Speed Limits in Austroads Guides

Speed limit setting has been covered by two Austroads Guides:

- The *Guide to Road Safety – Part 3: Speed Limits and Speed Management* (Austroads 2008a) provides a broad introduction to the role of speeds and speed limits in the Safe System, and outlines the general philosophy for choosing the speed limit in that context.
- The *Guide to Traffic Management – Part 5: Road Management* (Austroads 2008b Section 5) provides an introduction on the role of speed limits, and more detail on their selection and application.

The scope of this project directly supports the actions recommended by the Australian Transport Council (2011) relating to speed limits. The actions sought to develop new risk-based national speed limit guidelines for different road categories/functions, and to guide a review of speed limits on high-risk roads and intersections. Incorporation of the project findings in both Austroads Guides will meet the recommended actions.

During 2013–14, the Austroads project ST1888 *Strategic Review of the Austroads Road Safety Guide* will revise the aims of the *Guide to Road Safety – Part 3*. Without prejudicing the outcome of the review, some aspects of the model guidelines could be incorporated into the guide in future reviews.

The *Guide to Traffic Management – Part 5* currently offers practical guidance for the setting of speed limits, which forms the basis of the national practice. It is recommended that the model guidelines created by this project be considered as inputs into the next review of Part 5. Austroads project ST1762 *Towards the harmonisation of best practice speed limits* (completed in 2012–13) will also contribute inputs to this review.

There is a degree of duplication of speed limit setting guidance between the two Guides, e.g. in outlining the general philosophy and factors used in speed limit setting. Future Guide reviews should revise the content to be allocated to each guide.

10.2 Potential Changes to the Guide to Road Safety – Part 3

The model guidelines offer a number of suggested changes to the philosophy and approach to speed limit settings for higher-risk road lengths and intersections. The changes suggested in Table 10.1 may be considered in a future review of the *Guide to Road Safety – Part 3*. They relate to the Guide in its current form (Austroads 2008a).

Table 10.1: Suggested changes to the *Guide to Road Safety – Part 3 (Austroads 2008s)*

Existing Guide section	Suggestions and references to this report
Section 1.2 Speed and Safe System	This section can be expanded drawing on Section 3.1 and relevant parts of Australian Transport Council (2011). Figure 1.1 in the Guide should be replaced with a more updated version, such as the example in Figure 3.1. A discussion section should be provided on the harm minimisation/reduction approaches sourced from Section 3.4 and Section 3.5, noting that the guidance is based on harm reduction as a step towards the Safe System.
Section 1.3 Links between Travel Speed and Casualties	This section should be updated with the contents based on Section 3.2 and Section 3.3. The general form of the message may be retained with updates being limited to additional text, values, figures and references.
Section 4 How Do You Choose Speed Limit?	<p>Consider renaming this section of the Guide to 'Speed Limit Setting Philosophy'. Consider revising the structure and contents of this section using the structure based on the model guidelines. i.e.:</p> <p>Proposed '4.1 Background' noting the harm reduction approach (Section 8.1 and Section 8.2).</p> <p>Proposed '4.2 Recognition of Road Function' discussing the role of road function and drivers' mobility expectations from the transport system, i.e. road function. Parts of Section 4.2 of the Guide could be moved here and supplemented by Section 8.3.</p> <p>Proposed '4.3 Key Factors in Selecting Speed Limit' – this section could be supplemented by discussion in Section 3.5.1 and in Section 8.4, noting Figure 8.1.</p>
Section 4.1 Crash History	This section of the Guide provides a good summary of casualty crash risk, but could be re-pointed to severe crash risk, as a more Safe System-relevant measure. Consider changing the title to proposed '4.3.1 Severe Crash Rates'. Guidance would be needed for practitioners to identify what is high severe crash rate. The Guide may consider including Appendix B.1 of this report to explain how severe crash rates are calculated.
Section 4.2 Current Operating Performance	<p>Consider splitting this this section into two.</p> <p>One section (e.g. proposed '4.3.2 Road Use and Users') could be focussed on road use and users, drawing on risk factors for vulnerable road users, high AADT, or parking based on Section 4.2, and examples of road user triggers in Table 8.2 and Table 8.3.</p> <p>The second section (e.g. proposed '4.3.3 Speeds') could be focussed on existing speed distribution, drawing on the discussion on the increased crash risk due to speed variation in Section 3.3, and the preference for using mean speed in speed limit setting from Section 11. It would be worth noting that 85th percentile speed should not be used for speed limit setting in Australia.</p>
Section 4.3 Road and Roadside Infrastructure, Geometry and Roadside Development	This section could be retitled as proposed '4.3.1 Road Features' and re-focussed on the road infrastructure aspects of crash risk drawn from Section 4.2, and examples of road feature triggers in Table 8.2 and Table 8.3, and from Section 8.8 for intersections.
Appendix A and B	These should be thoroughly reviewed based on recent literature reviews in Section 5, and in Austroads (2010a), and additional updates at the time of the Guide review.
Appendix C	Reconsider the need for this appendix in view of how the practice has evolved in Australia.

10.3 Potential Changes to the Guide to Traffic Management – Part 5

The model guidelines provide a number of suggested changes to the selection process and the establishment of speed limits at higher-risk road lengths and intersections. The changes suggested in Table 10.2 may be considered in a future review of the *Guide to Traffic Management – Part 5*. They relate to Section 5 of the current Guide (Austrroads 2008b).

Table 10.2: Suggested changes to the *Guide to Traffic Management – Part 5* (Austrroads 2008b)

Existing Guide section	Suggestions and references to this report
Section 5.2 General Philosophy of Speed Limits, p 58	The introductory text in Section 8.1 and contents of Section 8.2, Section 8.3 and Section 8.4 could be used to focus greater emphasis within this section on the selection of typical speed limits dependent on road category and function in line with community expectations. Where severe crash risk is high (as indicated by crash rate history, road use patterns, road features and speeds), a lower speed limit may be considered. More in-depth content on speed limits philosophy should be directed to the <i>Guide to Road Safety – Part 3</i> .
Section 5.2 General Philosophy of Speed Limits, p 58	Consider adding an example of 'roads with substandard alignment'.
Section 5.2 Table 5.1: Speed limit practices	Consider expanding the table to cover a wider range of good speed zoning practice, e.g. adding to the 'Credibility' section another point such as 'a speed limit should be set in recognition of major severe crash risks which cannot be reasonably addressed by engineering improvements.' There could also be a new point relating to more frequent use of speed limit reminder signs.
Section 5.4.2, Table 5.3: General process for setting and reviewing speed limits	Consider reviewing this process using the process listed in Section 8.6. The revised process reflects the information needs of the model guidelines.
Section 5.4.2, Table 5.4: Summary of typical speed limits – Australia	Consider replacing the speed limit selection table for Australia with Table 8.2 and Table 8.3 from the model guidelines in Section 8.
Section 5.4.2 Establishing Speed Limits	Consider adding contents of Section 8.8 on localised (intersection) speed limits as a section or a sub-section.
Section 5.4.2 Establishing Speed Limits	Consider adding a section about minimum lengths of speeds zones based on information contained in Section 8.5.
Section 5.5 Signing of Speed Limits	Revise this section in light of suggested details in Section 8.9.
Section 5.6 Physical Speed Management Devices	Revise this section in light of suggested details in Section 8.10.

11. Discussion

The review of approaches to speed limit setting in the Safe System context was carried out in Section 3. Sections 3.4 and 3.5 considered two approaches to speed limits: harm minimisation and harm reduction. The latter forms the key focus of this project as it recognises that provision of Safe System infrastructure would be prioritised and delivered over many years. The harm reduction approach to speed limits follows existing community expectations in relation to the function of different road categories, rather than seek minimisation of severe crash risk at any cost. Thus, harm reduction may be considered a pragmatic approach to the question of speed limits, while taking steps towards the Safe System objectives.

Section 3.3 presented and discussed the relationship between speed variation and crash risk. There would be a benefit in replicating and updating the referenced UK studies in order to better understand this relationship in Australia and New Zealand. This would also help in updating the individual risk from speeding, an issue raised by the reference group during consultation. The question of speed limit targeting could also be investigated through such research.

An extensive review of severe crash risk factors was summarised in Section 4.2 and Appendix A, and was detailed in Appendix B, to inform the identification of higher-risk road lengths and intersections. The data available to the project limited some factors to being based on all-casualty crashes. Some factors could not be defined with any confidence. The following severe crash factors should be investigated further in order to strengthen the basis for speed limit setting guidance:

- crossing pedestrians vs traffic flow on urban roads
- cyclists along the route vs traffic flow on urban roads
- narrow clear zones and high hazard density on urban roads
- lack of left- and right-turn lanes on urban divided roads
- effect of minor-road traffic volume at outer-urban and rural high-speed intersections
- frequency of property entrances on rural and urban roads
- terrain type, (e.g. undulating or flat)
- frequency of curves on rural and urban roads
- traffic composition, e.g. percentage of heavy vehicles
- overall pavement quality in relation to the long-term viability of its maintenance
- level of accommodation of different road users, e.g. pedestrian crossings, overtaking lanes for heavy vehicles, on-road cyclist facilities.

Section 6 provided a number of examples of the application of reduced speed limits at higher-risk locations. While most of the identified trials showed reductions in crashes, the quality of trial methodologies and the robustness of findings varied. Many speed limit reductions were combined with other treatments. The effectiveness of future speed limit reductions at higher-risk locations cannot be stated with absolute confidence based on limited trials.

The current guidance on reduced speed limits at intersections in Section 8.8 was based on the limited trials and existing practice. Evaluations reported in Section 6.5 were limited in number and scope. Robust safety evaluations of speed limit change at intersections should be undertaken in Australia and New Zealand. Such studies should be based on before-and-after crash performance evaluation with control groups. Such a study could look at rural and urban intersections with different types of control, i.e. give way/stop sign, traffic signals and roundabouts.

The following points may be considered in future safety evaluations of reduced speed limits:

- selecting multiple high-risk locations for the trial, based on an established pattern of similar safety concerns
- if possible, limiting the treatments to speed limits only
- selecting multiple similar locations as control groups
- allowing for adequate before-and-after treatment periods, typically two years, or longer on lower-volume roads
- collecting ample before-and-after data (e.g. speeds, traffic volumes, crashes)
- estimating the net crash change at treatment sites by adjusting for crash change at non-treated sites
- estimating the robustness of the net crash change, e.g. standard error, confidence interval, statistical significance at a p -value ≤ 0.05 . Techniques such as ANOVA may be used for crash rates, or log-linear analysis for crash counts
- clearly qualifying any trial limitations (e.g. statistical significance, applicability to certain road type, noting other treatments/variables not accounted for).

In a departure from the past practice, the model guidelines in Section 8.7 propose to use mean speed to inform speed limit setting, rather than the 85th percentile speed used in the past. This represents a shift in focus from consideration of the speeding driver to the reasonable driver. This shift reflects lesser emphasis on the drivers' perception of the speed environment, and greater emphasis on the typical operation of the road, improved speed limit information and enforcement. The use of mean speed also acknowledges that speed limit, geometric design, and at times congestion, provide the strongest factors in driver speed selection.

Information on the speed distribution (e.g. standard deviation, coefficient of variation, percentage travelling 10, 20 and 30 km/h over the posted limit) should be considered in speed limit setting. Where the speed differential between vehicles is large, speed management techniques may need to be applied to reduce the top speeds towards the mean. These may include some of the speed management techniques identified via concurrent Austroads projects ST1426 *Methods for Reducing Speeds on Rural Roads – Compendium of Good Practice* and ST1768 *Achieving Safe System Speeds on Urban Arterial Roads*.

12. Summary and Conclusions

This project developed model national guidelines to assess and implement reduced speed limits on higher-risk roads and intersections not amenable to cost-effective engineering treatments. The model guidelines propose speed limit setting practice based on harm reduction, i.e. an intermediate step towards the Safe System. The model guidelines apply to different road categories and functions typical to Australia, while incorporating criteria for reduced speed limits based on severe crash risk:

- on road lengths that are narrow, have a substantial level of roadside hazards, have many intersections or property entrances, are curvilinear or undulating, or have higher than average severe casualty crash rates
- at higher-risk intersections, especially on high-volume outer-urban arterials, where engineering treatments are not feasible.

The model guidelines encourage consistent speed limits based on the presence of severe crash risks, while minimising multiple speed zones over short distances.

These objectives were achieved through review of the available research evidence and best practice in Australia, New Zealand and in other road safety leader countries. The model guidelines were developed in close consultation with Australian road agencies.

The intent of the model guidelines is to inform future revisions of the Austroads Guides on speed limits.

The model guidelines were informed by the review of the speed and crash risk relationships. The review also identified the relationship between speed variation and casualty crash risk on urban roads based on UK research. Further research in this field was recommended.

The report discussed the differences between harm minimisation and harm reduction approaches to speed limits. The project scope called for a harm reduction approach – an interim measure which retains most of the existing speed limits except where crash risk is particularly high. This necessitated selection of an appropriate approach to identify higher-risk roads and intersections.

A review of risk-assessment methods, existing guidelines, and examples of speed limit applications on higher-risk roads and intersections, suggested a combined approach to defining higher-risk roads by:

- high severe crash rates per kilometre of travel
- presence of vulnerable road users
- road features not safe for the road's function
- speeds incompatible with the road function and environment.

This approach was developed into a set of model guidelines for setting speed limits based on road category and function, with reduced speed limits recommended where one or more high-risk attributes were present. Also, a set of model guidelines was provided for reduced speed limits at high-speed intersection approaches, based on the limited evidence and existing jurisdiction practice.

The model guidelines also proposed to reduce the frequency of changes in speed limits experienced by drivers. This can be achieved through a proposed reduction in the available speed limit choices and extension of the minimum speed zone lengths. Practitioner judgement would still need to be applied to make sure that speed limits are broadly in line with the road character along the route.

These and other aspects of the model guidelines were trialled through hypothetical application to nominated road lengths and intersections in Queensland, Victoria and Western Australia. This was needed to ensure the application process was as easy and economical as possible. The trial included collection of relevant data and visits to selected sites. The trial resulted in a number of refinements incorporated into the final version of the model guidelines.

One of the project outcomes is a compendium of risk factors based predominately on fatal and serious injury crashes. This output will be of use in the further development of crash risk assessment based on Safe System objectives.

The project identified a number of knowledge gaps relating to severe crash risk factors and recommended their further investigation. Improving knowledge of severe crash risk factors will assist in progress towards minimising situations where fatal and severe injury crash risk is high, i.e. the Safe System objectives. Some of the actions may include the development of severe crash risk factors noted in Section 11 and Appendix B.17 (e.g. pedestrians vs traffic flow, clear zones on urban roads, turning lanes). Further evaluations of the safety effects of lower intersection speed limits were also recommended.

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Appendix A Compendium of Severe Crash Risk Factors

The following section presents the available severe crash risk factors taken into consideration during the development of the risk-based speed limit guidelines in Section 8.7. They are based on the review of recent research literature and data re-analysis of severe crash risk factors, reported in more detail in Appendix B and summarised in Section 4.2. The re-analysis was based on crash rate databases from Queensland, Victoria and New South Wales. The databases were developed and reported in previous projects (Austroads 2010a, 2010d; Jurewicz & Zivanovic 2011). Limitations are provided with individual tables and in Appendix B. Overall, the limitations mean that the severe risk factors should be treated as indicative in each jurisdiction.

Tables in Appendix A.1 represent severe risk factors identified for urban roads and intersections. Appendix A.2 provides similar factors for rural roads.

Each table focusses on a given road environment feature and provides a measure of the relative risk of a severe crash¹³ occurring in the presence of different categories of that feature. The value of 1.00 represents the safest category for the given road feature. Being based mostly on severe crash rates per 100 million VKT, the relative risks are a measure of the individual risk of a fatal or serious injury crash. These risk factors could be considered for use as severe crash modification factors in crash risk assessment or in black spot programs (subject to limitations).

The severity indices are also provided, where available, to illustrate how a change in the road feature category affects an individual's chance of sustaining a fatal or serious injury when involved in a casualty crash. The severity index for each road feature category was calculated by dividing all fatalities and serious injuries arising from casualty crashes involving a given road feature category by all persons involved in these crashes (injured or not). Some severity indices could not be calculated from the available data ('n.a.' in the tables).

It is important to note that the low reporting rates for minor casualty crashes would affect the accuracy of the severity indices reported, e.g. in remote areas. The severity index would be lower if all minor injury crashes were reported.

Table A 9, Table A 10 and Table A 11 also provide risk exposure factors based on AADT for rural and urban roads, respectively. These risk factors are based on crash counts rather than on crash rates, and they represent the change in the collective risk of severe crashes.

A.1 Urban Roads

Table A 1: Abutting land use

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Abutting land use	Commercial	1.42	0.22	Single carriageway, two-lane, urban roads with a 60 km/h speed limit.
	Residential	1.02	0.22	
	Industrial	1.00	0.26	

¹³ At least one fatal or serious injury outcome arising from a recorded casualty crash. Refer to Appendix B.1.

Table A 2: Access and intersection frequency

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Frequency of property entrances and intersections	Undivided and divided	1.00 + 0.25 x no. standard accesses per 100 m*	n.a.	Based on all casualty crashes.

* Based on casualty crashes, rather than fatal and serious injury crashes due to limited data.

Table A 3: Median

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Median	Undivided	1.36	0.23	-
	Divided	1.00	0.19	-

Table A 4: Lane width, divided roads

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Lane width urban – divided roads	< 3.5 m	2.2*	Inconclusive	Multi-lane, 80 km/h. Inconclusive for undivided roads, 60 km/h.
	≥ 3.5 m	1.0*		

* Based on casualty crashes, rather than fatal and serious injury crashes due to limited data.

Table A 5: Parking lanes, undivided roads

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Parking lanes – undivided roads	Yes	1.02	0.15	60 km/h roads.
	No	1.00	0.21	

Table A 6: Parking lanes, divided roads

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Parking lanes – divided roads	Yes	1.27	0.22	60, 70 and 80 km/h only.
	No	1.00	0.20	

Table A 7: Speed differential

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Individual driver speeds above the mean traffic speed	+10 km/h	4.12 ⁽¹⁾	n.a.	Lowering the speed limit could be used to reduce the percentage of drivers seeking to travel at a higher speed than the mean, when the mean is already well below the existing speed limit ⁽²⁾ .
	+5 km/h	1.89	n.a.	
	+0 km/h	1.00	n.a.	

1 Based on casualty crashes, rather than fatal and serious injury crashes due to limited data.

2 A percentage of drivers will seek to drive at speeds close to the speed limit even when conditions are not ideal (e.g. between traffic signal queues, straights between bends or traffic calming devices). In-depth crash investigations suggest that individual driver speeds well above the mean speed significantly increase the individual risk of a casualty crash (Austroads 2010a based on Kloeden, Ponte & McLean 2001, Kloeden, McLean & Glonek 2002).

Table A 8: Intersection severe crash risk factors

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Intersections	3-leg traffic lights	2.30	n.a.	Results in this table may be confounded by complex nature of urban intersections, e.g. give-way intersections include both freeway merge ramps and give-way sign intersections in outer metro areas.
	4-leg stop/give-way	1.97		
	3-leg stop/give-way	1.73		
	4-leg traffic lights	1.27		
	3-leg roundabout	1.00		
	4-leg roundabout	0.72*		

* Figure based on limited severe crash data.

Table A 9: Risk exposure factors, undivided 60 km/h roads

Road environment feature	Categories	Risk exposure factor	Severity index	Notes
AADT	48 000	2.09	n.a.	Based on undivided urban roads, 60 km/h speed limit. Not high enough to be considered a high-risk factor (borderline).
	36 000	1.62		
	28 000	1.31		
	20 000*	1.00		

* State road network average for this stereotype in Victoria. Risk exposure factors relate to collective risk of severe crashes, i.e. crash numbers. High traffic volumes result in higher crash numbers, unless crash risk is reduced in other ways (e.g. upgrade of road stereotype, or reduced access).

Table A 10: Risk exposure factors, divided 80 km/h roads

Road environment feature	Categories	Risk exposure factor	Severity index	Notes
AADT (per carriageway)	56 000	2.06	n.a.	Based on divided urban roads, 80 km/h speed limit.
	44 000	1.67		
	36 000	1.41		
	24 000*	1.00		

* State road network average for this stereotype in Victoria. Risk exposure factors relate to collective risk of severe crashes, i.e. crash numbers. High traffic volumes result in higher crash numbers, unless crash risk is reduced in other ways (e.g. upgrade of road stereotype, or reduced access).

Table A 11: Risk exposure factors, divided 100 km/h roads

Road environment feature	Categories	Risk exposure factor	Severity index	Notes
AADT (per carriageway)	88 000	2.05	n.a.	Based on divided urban freeways, 100 km/h speed limit. Not high enough to be considered a high-risk factor.
	76 000	1.62		
	64 000	1.27		
	52 000*	1.00		

* State road network average for this stereotype in Victoria. Risk exposure factors relate to collective risk of severe crashes, i.e. crash numbers. High traffic volumes result in higher crash numbers, unless crash risk is reduced in other ways (e.g. upgrade of road stereotype, or reduced access).

A.2 Rural Roads

Table A 12: Pavement type

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Pavement type	Unsealed	2.53	0.28	Single carriageway rural roads, 100 km/h speed limits.
	Sealed	1.00	0.32	

Table A 13: Presence of median

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Median	Undivided	2.97	0.31	-
	Divided	1.00	0.24	

Table A 14: Lane width, divided roads

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Lane width – divided roads	< 3.7 m	2.1*	Inconclusive	Multi-lane roads, 110 km/h.
	≥ 3.7 m	1.0*		

* Based on casualty crashes, rather than fatal and serious injury crashes due to limited data. The vast majority of roads in the sample had lane widths of 3.5–3.6 m, i.e. the < 3.7 m category.

Table A 15: Lane width, undivided roads

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Lane width – undivided roads	< 3.0 m	1.5*	Inconclusive	Two-lane roads, 100 km/h.
	≥ 3.0 m	1.0*		

* Based on casualty crashes, rather than fatal and serious injury crashes due to limited data.

Table A 16: Sealed shoulder width

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Sealed shoulder width*	0.5 m	1.69	0.34	Single carriageway rural roads with 100 km/h speed limit.
	1.0 m	1.37	0.32	
	1.5 m	1.18	0.31	
	2.0 m	1.00	0.31	

* The effect of unsealed shoulders, or lack thereof, was not controlled for.

Table A 17: Sealed and unsealed shoulder widths (run-off-road crashes only)

Road environment feature	Categories	Relative risk of casualty run-off-road crashes	Severity index	Notes
Sealed and unsealed shoulders	No sealed shoulder, no unsealed shoulder	9.00*	n.a.	Based on run-off-road casualty crash risk, 100 km/h rural undivided roads.
	Narrow sealed shoulder ≤ 0.5 m, no unsealed shoulder	5.00*	n.a.	
	Narrow sealed shoulder ≤ 0.5 m, narrow unsealed shoulder ≤ 1.0 m	3.50*	n.a.	
	Sealed shoulder 0.6–1.0 m, narrow unsealed shoulder ≤ 1.0 m	1.50*	n.a.	
	Sealed shoulder 1.1–1.5 m, unsealed shoulder 1.1–1.5 m	1.00*	n.a.	

* Based on casualty crashes, rather than fatal and serious injury crashes due to limited data.

Table A 18: Clear zone width

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Clear zone width	0–2 m	2.27	0.62	100 km/h rural single carriageway roads (sections with barriers excluded).
	2–4 m	1.13	0.47	
	4–8 m	1.03	0.55	
	> 8 m	1.00	0.54	

Table A 19: Roadside hazard density

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Hazard density per 100 m of roadside	> 50	1.73	0.60	100 km/h single carriageway rural roads in Victoria (barriers excluded). Continuous flexible barriers were shown to deliver severe crash likelihood reductions.
	25–50	1.16	0.57	
	8–25	1.11	0.60	
	< 8	1.00	0.45	

Table A 20: Horizontal alignment

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Horizontal curve frequency per 10 km	60	4.46*	n.a.	Based on casualty crashes, rural single carriageway roads.
	40	2.86*		
	20	1.71*		
	10	1.30*		
	5	1.14*		
	1	1.03*		

* Based on casualty crashes, rather than fatal and serious injury crashes due to limited data.

Table A 21: Terrain

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Terrain	Undulating	4.50*	n.a.	Based on casualty crashes, rural single carriageway roads.
	Flat	1.00*		

* Based on casualty crashes, rather than fatal and serious injury crashes due to limited data.

Table A 22: Speed differential

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Individual driver speeds above the mean traffic speed	+10 km/h	2.20 ⁽¹⁾	n.a.	Lowering the speed limit could be used to reduce the percentage of drivers seeking to travel at a higher speed than the mean, when the mean is already well below existing speed limit ⁽²⁾ .
	+5 km/h	1.45	n.a.	
	+0 km/h	1.00	n.a.	

1 Based on casualty crashes, rather than fatal and serious injury crashes due to limited data.

2 A percentage of drivers will seek to drive at speeds close to the speed limit even when conditions are not ideal (e.g. between traffic signal queues, on straights between bends or traffic calming devices). In-depth crash investigations suggest that individual driver speeds well above the mean speed significantly increase the individual risk of a casualty crash (Austroads 2010a based on Kloeden et al. 2001, 2002).

Table A 23: Rural intersection severe crash risk factors

Road environment feature	Categories	Relative risk of severe crashes	Severity index	Notes
Intersections	4-leg stop/give-way	4.68	n.a.	-
	3-leg stop/give-way	3.34		
	4-leg traffic lights	2.83		
	3-leg traffic lights	1.85		
	4-leg roundabout	1.66*		
	3-leg roundabout	1.00		

* Figure based on limited severe crash data.

Table A 24: Risk exposure factors, undivided 100 km/h roads

Road environment feature	Categories	Risk exposure factor	Severity index	Notes
AADT	12 000	2.14	n.a.	Based on undivided rural roads, 100 km/h speed limit.
	8 000	1.71		
	5 000	1.32		
	3 000*	1.00		

* State road network average for this stereotype in Victoria. Risk exposure factors relate to collective risk of severe crashes, i.e. crash numbers. High traffic volumes result in higher crash numbers, unless crash risk is reduced in other ways (e.g. upgrade of road stereotype, or reduced access).

Table A 25: Risk exposure factors, rural divided highways, 100 km/h

Road environment feature	Categories	Risk exposure factor	Severity index	Notes
AADT	28 000	1.26	n.a.	Based on divided rural freeways 110 km/h speed limit.
	20 000	1.13		
	14 000*	1.00		

* State road network average for this stereotype in Victoria. Risk exposure factors relate to collective risk of severe crashes, i.e. crash numbers. High traffic volumes result in higher crash numbers, unless crash risk is reduced in other ways (e.g. upgrade of road stereotype, or reduced access).

Table A 26: Risk exposure factors, rural freeways, 110 km/h

Road environment feature	Categories	Risk exposure factor	Severity index	Notes
AADT	14 000	2.33	n.a.	Based on divided rural freeways 110 km/h speed limit.
	12 000	2.00		
	10 000	1.67		
	8 000	1.33		
	6 000*	1.00		

* State road network average for this stereotype in Victoria. Risk exposure factors relate to collective risk of severe crashes, i.e. crash numbers. High traffic volumes result in higher crash numbers, unless crash risk is reduced in other ways (e.g. upgrade of road stereotype, or reduced access).

Appendix B Review of Severe Crash Risk Factors

This appendix provides the results of a literature review and crash rates data re-analysis relating to the features and characteristics of higher-risk roads (severe crash risk factors). The findings were based on recent projects, Austroads (2010a, 2010d) and Jurewicz and Zivanovic (2011), and other relevant research literature.

These findings were summarised in Section 4.2 and were used to discuss and select the severe crash risk factors used in the model guidelines in Section 8.7. The severe crash risk factors have been summarised by urban/rural environment in Appendix A.

It should be noted that many of these findings may be based on studies using limited data. The findings where re-analysis was carried out need to be interpreted in the light of being based on:

- crash data sourced from a single jurisdiction
- road data that was categorical, not continuous (e.g. ≤ 3.5 m, > 3.5 m)
- data sample sizes that varied for each category, hence each risk factor is likely to be of different accuracy
- error analysis not being provided for some risk factors
- data being sourced from different environments of each road stereotype (e.g. rural divided and undivided roads), and hence, subject to different operating conditions.

For these reasons, the findings should be considered as indicative when applied in each jurisdiction. Verification of these findings through similar studies across different parts of Australia would be desirable.

B.1 Crash Rates

Austroads (2008a) states that the most important consideration in the assessment or review of a speed limit is the crash history of the road.

A road's crash history can be viewed as either collective risk or individual risk, as follows:

- Collective risk is a crash rate of high-severity (fatal and serious) crashes per kilometre of road or per site (e.g. an intersection). Collective risk expresses the risk to the travelling community at a given location.
- Individual risk is a crash rate of high-severity crashes per 100 million vehicle kilometres travelled (100 M VKT) at a given location. It is in effect a measure of the likelihood of an individual road user being involved in a severe crash.

Austroads (2008a) warns that collective risk, or crash rate per km, should be used with caution when attempting to reduce speed limits. This issue was explored in Section 3.5.1.

The crash rate per 100 M VKT for a particular road is usually compared to a mean for the road category, or against a nominated warrant (e.g. as in selection of black spots). Roads with crash rates significantly above the mean may attract investigation and possible improvements. A critical crash rate may also be selected. Locations with crash rates above the critical value may receive a higher priority for treatment. Critical crash rates may be set using a percentile, e.g. 85% of similar sites in the jurisdiction have a crash rate lower than critical.

The mean severe crash rate for a given road category can be estimated from a sample of road sections of that category across the network. Equation A1 shows how this can be done for road lengths. The larger the sample of road sections, the more accurate the estimate of the severe crash rate.

$$\text{Severe crash rate} = \frac{\sum (\text{F crashes} + \text{SI crashes})}{365 \times T \times 10^8 \times \sum (\text{Length} \times \text{AADT})} \quad \text{A1}$$

where

- F crashes = number of fatal crashes that occurred on each selected road section over a time period of T years
- SI crashes = number of serious injury crashes that occurred on each selected road section over a time period of T years
- T = the selected time period in years, typically five years
- Length = length of each section in kilometres
- AADT = annual average daily traffic on each road section

A similar process can be followed for intersections. Alternatively, by assuming a constant length of each leg (e.g. 100 m) and considering only the AADT entering the intersection on each leg, the severe crash rate can be calculated ignoring the L variable, i.e. per 100 million VE, or vehicles entering.

Crash rates enable comparisons between the relative safety of similar roads and intersections according to road stereotype, environment, function, and various other attributes (ARRB Group 2007). Crash rates can assist in prioritising infrastructure improvements to improve safety on the road network. For example, on rural undivided roads where run-off-road crash rates were high, wire-rope barrier may be installed on the road sections with the highest crash rates.

The Austroads Crash Rates Database was created for all Australian jurisdictions, combining crash data with road feature data and traffic flow data, and thus providing a platform for detailed analysis of crash risks (Austroads 2010d). Analysis of various relationships between road characteristics and crash outcomes can be performed using the database, such as the influence of speed limits on crash rates and crash severity.

Austroads (2010d) suggests that casualty crash rates were not comparable between jurisdictions due to differences in crash reporting definitions and reporting rates. It is generally possible to compare fatal crash rates as the definition is common across Australia and New Zealand (death within 30 days of the crash), and such severe crashes were almost always reported to the police. There are current initiatives to make fatal and serious injury rates more comparable through verification of police crash information with hospital admissions data.

B.2 Pavement Type

The analysis carried out by Jurewicz and Zivanovic (2011) was able to quantify the effect of sealed pavement on the risk of all recorded and severe crashes, as shown in Table B 1. Only single-carriageway, 100 km/h rural roads were used in the crash rate calculations in order to control for confounding variables as much as possible. Only 2002–07 data from the Queensland crash rates database was analysed in this study. The database was described in Austroads (2010d). The database contained detailed information about most of the Queensland declared road network (i.e. state controlled) between 2002 and 2007.

It is clear from this table that the likelihood of severe crashes is much higher on unsealed roads. Even so, non-engineering variables may contribute to these relative risks, such as remote location and lack of access to emergency services, under-reporting of minor injury crashes, vehicle type in remote areas, and road user issues such as speed, impaired driving and fatigue.

Table B 1: Relative risks and severity indices for sealed/unsealed rural roads (100 km/h)

Pavement	Relative crash risk	Relative fatal and serious injury crash risk	Severity index
Unsealed	2.91	2.53	0.28
Sealed	1.00	1.00	0.32

Source: Jurewicz and Zivanovic (2011).

B.3 Traffic Flow

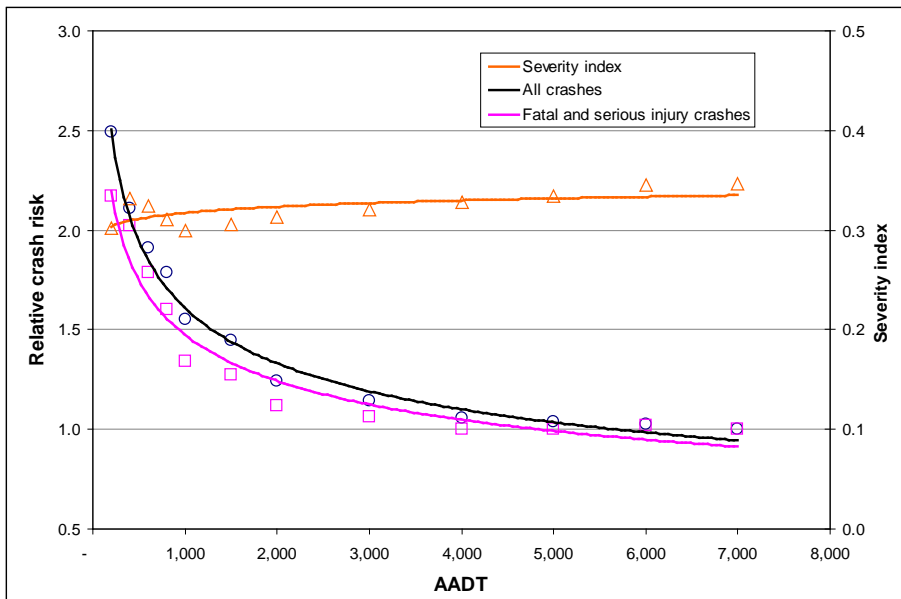
Traffic flow, expressed as average annual daily traffic (AADT) in vehicles per day (vpd), is one of the key determinants of individual risk (crash likelihood) on rural roads.

Jurewicz and Zivanovic (2011) showed the relationship between AADT and the likelihood of severe crashes (fatal and serious injury outcome) and the typical crash severity. The analysis was performed for undivided, sealed rural roads in Queensland with a 100 km/h speed limit. To control for other variables, the data sample consisted of two-lane rural state roads, with lanes 3.3–3.5 m wide, and average sealed shoulders 0.8–1.2 m wide. Figure B 1 presents these results, which show how the relative risk based on severe crash rates per 100 M VKT decreased with increasing traffic volume. Hence, it should be of concern if the severe crash rate is higher than the average for the given road type and traffic volume. Similar crash rate functions can be developed for different road stereotypes in each jurisdiction.

It is noted that minor injury crashes are substantially under-reported in rural areas. This problem is further exacerbated in remote areas, where traffic volumes are expected to be low. This has a potential effect of masking the true nature of the crash severity relationship in Figure B 1.

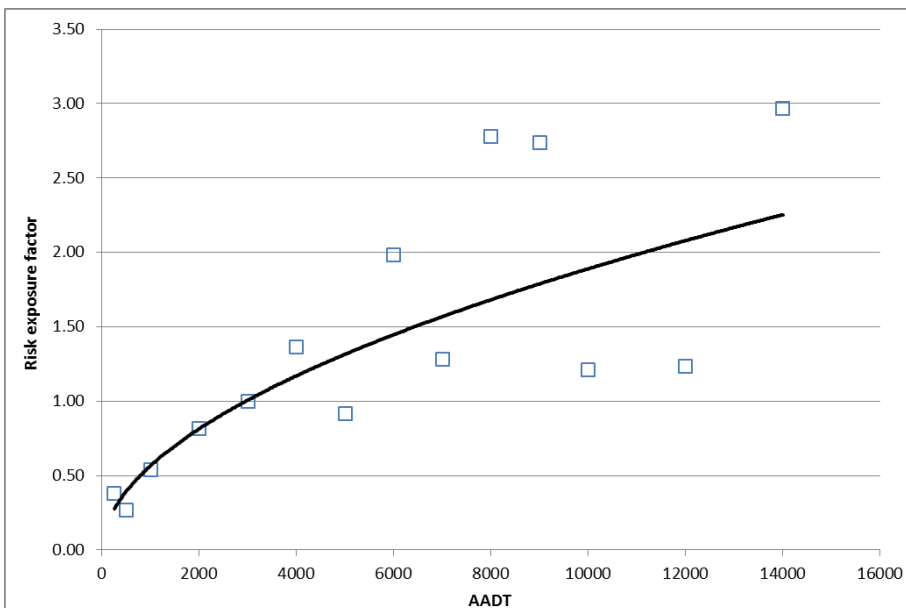
The same data can be interpreted in terms of the collective risk, namely the frequency of crashes per kilometre or per site (e.g. at intersections). The relationship is reversed, i.e. there are more crashes per kilometre with increasing traffic volume, as shown in Figure B 2 based on Victorian undivided rural roads with a 100 km/h speed limit. The risk changes shown in Figure B 2 are relative to AADT 3000 vpd, the mean for the state road network of this type. This is due to increased exposure to other risk factors such as intersections, curves, or roadside hazards. Hence, AADT can be considered a risk exposure factor, a different type of indicator than a risk factor. High AADT values for a given road stereotype can be typically associated with high crash numbers. Thus, high volume roads may be considered more high-risk than low volume roads, given the same road infrastructure.

Figure B 1: Example of the effect of traffic volume on severe crash likelihood on undivided rural roads (100 km/h)



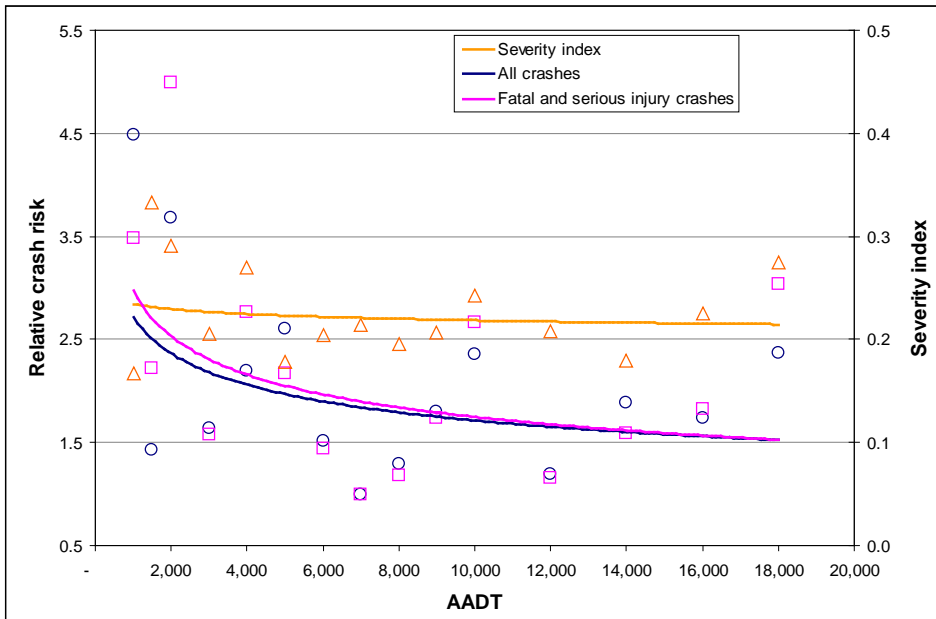
Source: Jurewicz and Zivanovic (2011).

Figure B 2: Example of the effect of traffic volume on severe crash frequency on undivided rural roads (100 km/h, Victorian data)



Single-carriageway 60 km/h roads in urban areas were analysed in a similar way, as shown in Figure B 3, based on Queensland data. Traffic volume played a less clear role in the urban environment, due to more complex traffic movements, congestion, and interactions with non-driving road users (indicated by the scatter of data points). It was evident, however, that the likelihood of a crash decreased strongly with increasing traffic volume (Jurewicz & Zivanovic 2011).

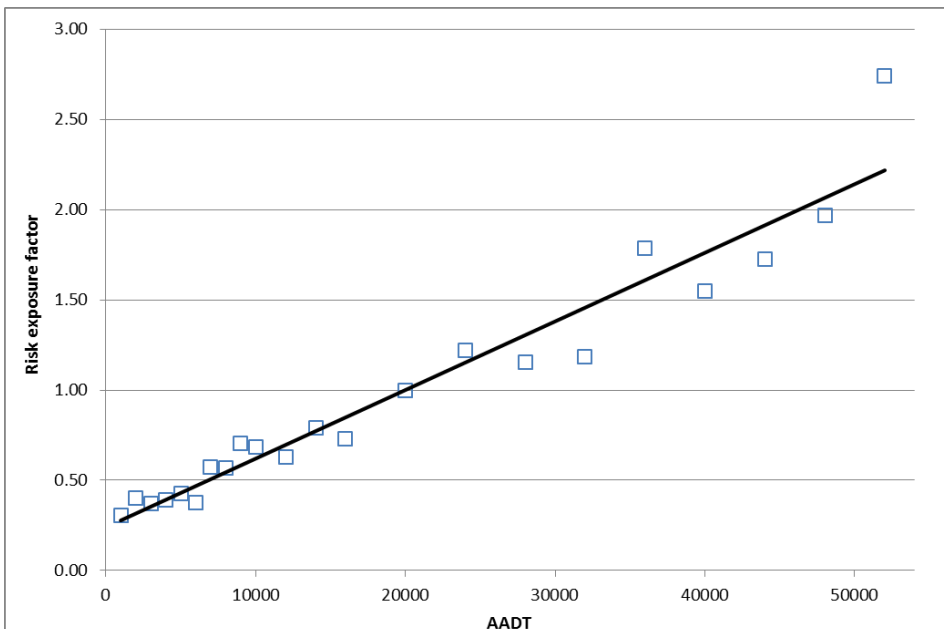
Figure B 3: Example of the effect of traffic volume on severe crash likelihood on single-carriageway urban roads (60 km/h, Queensland data)



Source: Jurewicz and Zivanovic (2011).

As expected, the risk exposure factor also strongly increased with traffic volume, as indicated on Figure B 4 based on Victorian data. The exposure risk shown is relative to AADT 20 000 vpd, the mean for the state road network.

Figure B 4: Example of the effect of traffic volume on severe crash frequency on undivided urban roads (60 km/h, Victorian data)



B.4 Pedestrians

A limited investigation on the effect of pedestrian movements on crash risk was undertaken during the 2012–13 stage of the project. No sources could be identified that described the risk of severe crashes. Nevertheless, there have been studies relating the effect of vehicle flow and crossing pedestrians to pedestrian casualty crashes.

Brude and Larsson (1993), presented in Erke and Elvik (2007), provided equations estimating pedestrian crash numbers from entering AADT and average hourly pedestrian crossing volumes at junctions in Sweden. The equations suggested a decreasing crash rate in response to higher vehicle or pedestrian volumes. Erke and Elvik did not provide a detailed description of the models (e.g. crash severity level).

Turner, Rozenburg and Francis (2006) developed New Zealand models for the annual frequency of pedestrian casualty crashes at midblock locations based on AADT and daily crossing pedestrian numbers. Equation A2 presents the model.

$$\text{Pedestrian casualty crashes p.a.} = 1.86 \times 10^{-4} \times Q^{0.692} \times P^{0.256} \times L \quad \text{A2}$$

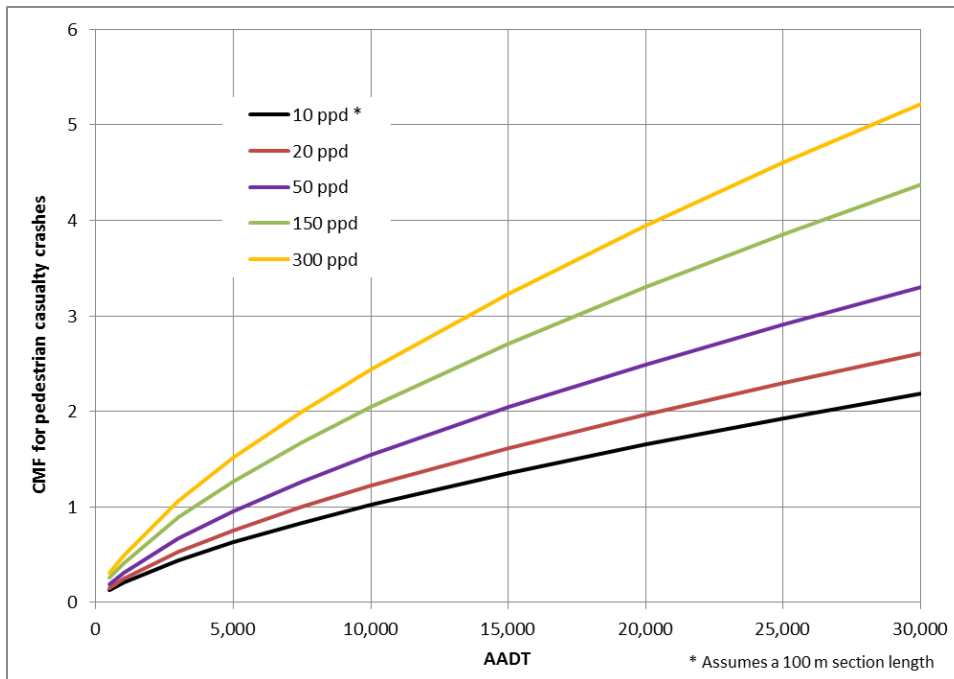
where

- Q = two-way AADT along the section (vpd)
- P = number of pedestrians crossing the section per day (ppd)
- L = length of the section in kilometres

As with the Swedish model, the crash rate decreases with greater vehicle and pedestrian flows. This is indicated by both power exponents being < 1. This effect has been referred to as ‘safety in numbers’ by Erke and Elvik (2007) and by other authors. While it is true that the individual risk is decreasing, this sort of description may be misleading. The absolute crash numbers (i.e. the collective risk) are still increasing with higher AADT and higher pedestrian crossing numbers, hence, in absolute terms safety is being reduced.

Figure B 5 presents changes in pedestrian casualty crash risk with AADT and pedestrian crossing numbers, as per Equation A2, relative to AADT of 7500 vpd and pedestrian volume of 20 ppd. The dose-response relationship is positive for both variables, i.e. crash risk increases with exposure.

Figure B 5: Pedestrian casualty crash risk changes with AADT and pedestrian crossing volumes



Source: Based on Turner, Roozenburg and Francis (2006).

These relationships could be used to define thresholds for speed limit reduction based on the mix of vehicle flow and crossing pedestrians. Table B 2 presents several thresholds where pedestrian casualty crash risk is doubled from the baseline used in Figure B 5. Adjustment of baseline risk levels would produce different threshold values.

Table B 2: AADT and crossing pedestrian thresholds where pedestrian casualty crash risk is doubled

AADT	Pedestrians crossing per day (100 m section)
7 500	300
15 000	50
20 000	20
30 000	10

Note: Baseline risk taken at AADT of 7500 vpd and 20 ppd per 100 m section.

It is likely that this relative relationship between pedestrian casualty crashes, traffic and pedestrian volumes presented in this section would remain very similar for fatal and severe pedestrian crashes. The two independent variables have little impact on the severity of crash outcomes. There is a theoretical link between traffic lane flow and average speed; however, this would be unlikely to affect a relationship drawn from long-term data collected across different parts of the road network.

Speed limits, and presumably traffic speeds, were shown to affect the severity of pedestrian casualty crashes. Analysis of Victorian crash data under a concurrent Austroads project (ST1767) showed that 48% of pedestrian casualty crashes at urban signalised intersections resulted in severe injuries. This proportion varied with speed limit and was 46% at 40 km/h, and 58% at 80 km/h. The observation does not imply causality; however, meta-analysis of before-and-after speed limit reduction studies by Elvik (2009) suggests that reduction in speed limits and mean speeds will lead to reductions in crash likelihood and severity in most cases. This needs to be considered separately to the relationship in Figure B 5.

B.5 Cyclists

A similar review was carried out for the effect of cyclist flow mixing with traffic. Turner, Roozenburg and Francis (2006) developed New Zealand models for the annual frequency of cyclist casualty crashes at midblock locations based on AADT and daily two-way bicycle flow. Equation A3 presents the model.

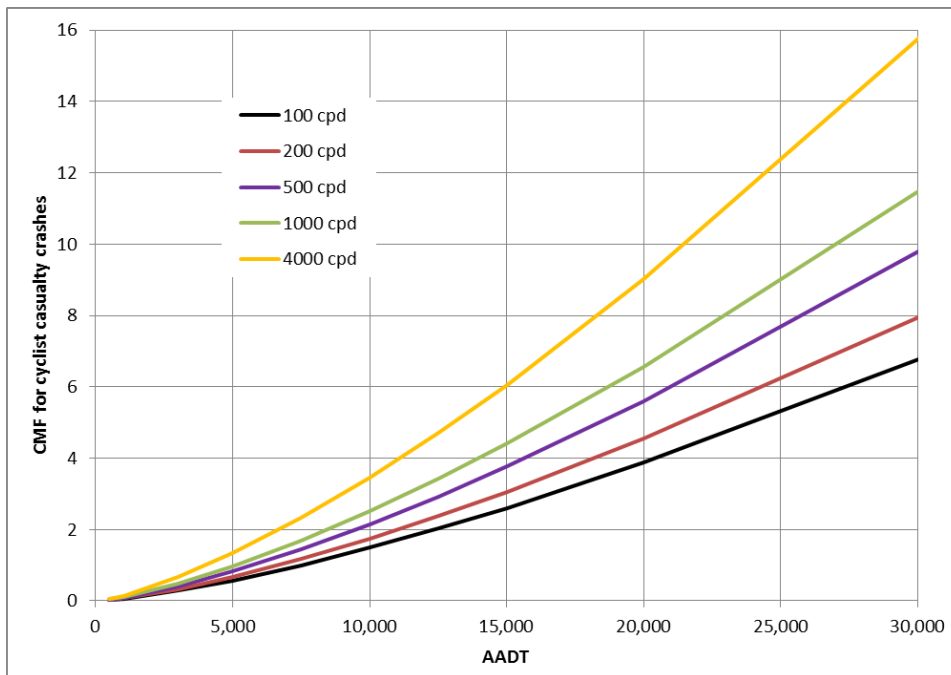
$$\text{Cyclist casualty crashes p.a.} = 1.73 \times 10^{-7} \times Q^{1.38} \times C^{0.229} \times L \tag{A3}$$

where

- Q = vehicle AADT for the road section (vpd)
- C = two-way cycle flow per day (cpd)
- L = length of the section in kilometres

Figure B 6 presents the relationship with the CMF relative to AADT of 7500 vpd and 100 cpd. The crash risk is noted to increase with growing AADT, as indicated by the Q power exponent value above 1. In fact, traffic flow has the dominant role in determining the cyclist crash risk. The influence of cyclist flow appears comparatively minor. The relationship suggests that a small number of cyclists mixing with high volumes of vehicular traffic will lead to a high risk of casualty crashes for cyclists.

Figure B 6: Cyclist casualty crash risk changes with AADT and daily cyclist flow



Source: Based on Turner, Roozenburg and Francis (2006).

The practical application of this relationship may be in the recognition of high volume roads as generally hazardous for cyclists. Reduced speed limits may assist in reducing cyclist crash risk if other forms of road user separation are not possible.

The relationship in Figure B 6 could be used to define thresholds for speed limit reduction based on the vehicle and cyclist flow mix. Table B 3 presents several thresholds where cyclist casualty crash risk is doubled from the baseline used in Figure B 6. Adjustment of baseline risk levels would produce different threshold values.

Table B 3: AADT and daily cyclist flow thresholds where cyclist casualty crash risk is doubled

AADT	Cyclists per day
7 500	2060
10 000	360
20 000	10
30 000	0.5

Note: Baseline risk taken at AADT of 7500 vpd and 100 cpd.

Analysis of crash data in Victoria under the concurrent Austroads project ST1767 suggested that 32% of cyclist crashes at urban signalised intersections resulted in severe injuries. This proportion varied with the speed limit and was between 24% at 40 km/h, and 41% at 80 km/h. This needs to be considered separately to the relationship in Figure B 6.

B.6 Abutting Land Use

Analysis of crash rate data by Jurewicz and Zivanovic (2011) showed that the type of roadside development made a noticeable difference in selected urban environments. Table B 4 confirms the anecdotal evidence that crash likelihood is much higher in commercial precincts, as tested on a sample of single-carriageway, two-lane, urban roads with a 60 km/h speed limit (Queensland). The lower relative risk of severe crashes indicates that a high proportion of the crashes were of low severity in this particular environment (confirmed by the low severity index).

Table B 4: Relative risks and severity indices of crashes in different urban land use environments

Roadside development (urban only)	Relative crash risk	Relative fatal and serious injury crash risk	Severity index
Commercial (businesses, retail trades)	1.72	1.42	0.22
Residential (private dwellings)	1.21	1.02	0.22
Industrial (factories, wholesale trades)	1.00	1.00	0.26

Source: Jurewicz and Zivanovic (2011).

Lower speed limit initiatives targeting such routes have been shown to reduce crashes, especially for vulnerable road users (e.g. Scully, Newstead & Corben 2008), although the results were not robust.

B.7 Frequency of Property Entrances and Intersections

Access and egress manoeuvres at driveways and minor intersections were believed to contribute significantly to the risk of crashes. Jurewicz and Zivanovic (2011) carried out an analysis to confirm this relationship using all-casualty crash and access frequency information obtained from VLimits 2.0 data from Victoria¹⁴. The sample included over 1100 road sections with varying density of access. Access points of different types were standardised according to the VLimits 2.0 weighting shown in Appendix D.

¹⁴ VLimits 2.0 is a Victorian online speed limit selection expert system. It collects substantial amounts of road information to provide a suggested speed limit, including the access frequency. Intersections are converted to standard access points using a weighting system.

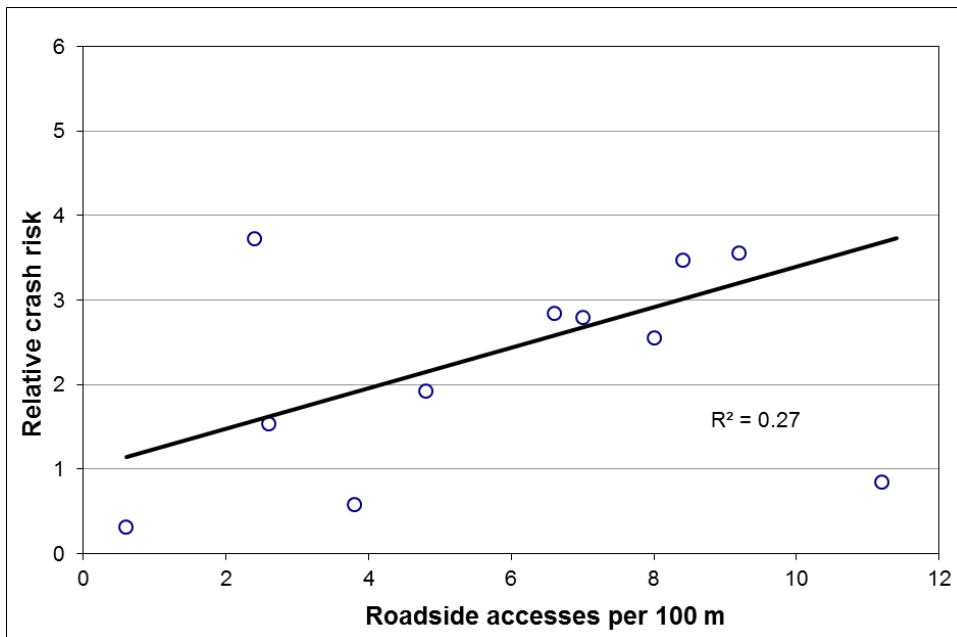
Higher access frequency was found to increase casualty crash likelihood (relative risk) on all urban arterial roads. The degree of correlation between the two variables was low in all cases, suggesting that there were many other confounding variables affecting crash frequency. Figure B 7 shows an example of the relationship based on 60 km/h, undivided urban arterials in a fully built-up urban environment. The relationships developed for 70 and 80 km/h divided urban arterials were very similar. Because of this similarity, a general relationship between casualty crash likelihood and the number of standardised access points was created, applicable to all built-up areas. It shows that on average, the casualty crash relative risk increase was dictated by:

$$RR_{cas} = 1.00 + 0.25 \times \text{no. accesses per 100 m} \quad A4$$

The standardised access points per 100 m are calculated according to the simple weighting method used by all XLimits-type speed limit setting programs, e.g. VLimits 2.0, QLIMITS 3.0, WALIMITS 3.0, USLimits 2.0. The method assigns a weighting to each access point dependent on the intensity and type of traffic contribution to the main road, e.g. 1 for residential access, 2 for commercial access, 3 for a signalised intersection or a roundabout.

For roads in partially built-up, sparsely built-up and rural areas, the relationships were generally unclear. Driveways were less frequent on these roads and did not seem to affect crash risk.

Figure B 7: Effect of road access frequency on casualty crash risk for fully built-up single-carriageway arterials



Source: Jurewicz and Zivanovic (2011).

The crash severity effects of access frequency could not be investigated using the available data. It is likely that higher access frequency would contribute to an increased proportion of right-angle casualty crashes, which were generally more severe. Also, increased access frequency may suggest greater residential and business activity, hence, more vulnerable road users. Again, this would tend to increase the average crash severity.

B.8 Median Presence and Width

Crash risk is strongly dependent on the road category (environment, design stereotype, speed limit). One of the key factors was the presence or the lack of a median (i.e. single- vs dual-carriageway). The amount of control of turning and crossing movements, direct access limitations, frequency of minor intersections, and typical speed limits and speeds all contribute to crash risk. Table B 5 shows that the lack of a median had a more profound effect on the likelihood of severe crashes than on all recorded crashes. The results are based on a review of the Queensland crash, traffic volume and road stereotype database described in Austroads (2010d). The database contained detailed information about most of Queensland's declared road network (i.e. state controlled) between 2002 and 2007.

Table B 5 shows that dual-carriageway roads had a consistently lower likelihood of crashes. Single-carriageway roads were relatively less safe in the rural environment than in the urban environment (the crash rates were higher), most probably due to the higher speeds.

Table B 5: Relative risks and severity indices of crashes on different road design stereotypes

Environment	Road design stereotype	Relative crash risk	Relative fatal and serious injury crash risk	Severity index
Rural	Single-carriageway	2.30	2.97	0.31
	Dual-carriageway	1.00	1.00	0.24
Urban	Single-carriageway	1.15	1.36	0.23
	Dual-carriageway	1.00	1.00	0.19

Source: Jurewicz and Zivanovic (2011).

Narrow median width can also contribute to a road being of higher risk. Jurewicz and Zivanovic (2011) observed the following changes in crash risk (any severity) for divided roads with medians wider than 4.5 m when compared with those with narrower medians:

- no change on 70 km/h speed limit roads
- lower on 80 km/h speed limit roads with wider medians.

All divided roads with a 100 or 110 km/h speed limit in the analysis sample had medians wider than 4.5 m. The relationship was not clear for 60 km/h divided roads.

B.9 Lane Width

Jurewicz and Zivanovic (2011) reported on the crash risk according to lane width for sealed single-carriageway rural roads with 100 km/h speed limits based on the Queensland crash rates database. The results presented in Table B 6 show that narrow traffic lanes (2.7 m) were associated with a much higher likelihood of a casualty crash. This result may be correlated with a number of other risk factors, such as poor alignment and unsafe roadsides. On the other hand, an increased lane width in the 3.1–3.6 m range had a moderate effect on reducing the likelihood of a casualty crash. Lane width did not seem to have a clear impact on the likelihood of severe crashes; the relationship based on a limited data sample was inconclusive.

Table B 6: Relative risks and severity indices for 100 km/h rural roads of different lane widths

Lane width (m)	Relative crash risk	Relative fatal and serious injury crash risk	Severity index
2.7	5.34	n.a.	n.a.
2.8	1.72	n.a.	n.a.
3.0	1.58	1.07	0.28
3.1	1.46	n.a.	n.a.
3.2	1.46	1.19	0.33
3.3	1.49	1.39	0.38
3.4	1.32	n.a.	n.a.
3.5	1.27	1.00	0.32
3.6	1.34	1.39	0.42
3.7	1.00	n.a.	n.a.

Source: Jurewicz and Zivanovic (2011).

The effect of lane widths on single-carriageways in urban areas was also analysed, however the results produced no clear relationship. Urban roads have many additional crash risk factors that mask the influence of lane width, such as parking and access density.

B.10 Sealed Shoulders

The Jurewicz and Zivanovic (2011) analysis of the effect of sealed shoulder widths on the safety performance of single-carriageway rural roads in Queensland is presented in Table B 7. Again, the Queensland crash rates database was utilised to compare crash risks for different road features. In order to control for confounding variables, the analysis was restricted to 100 km/h roads with lane widths in the 3.3–3.5 m range. Also, the average of the sealed shoulder widths on both sides of the road was used. It is clear that increased sealed shoulder width provided an improvement in safety performance, particularly for severe crashes. Table B 7 also indicates that the typical crash severity fell incrementally with increasing sealed shoulder width.

Table B 7: Relative risks and severity indices for sealed shoulder widths on single-carriageway rural roads (Queensland, 100 km/h)

Average sealed shoulder width (m)	Relative crash risk	Relative fatal and serious injury crash risk	Severity index
0	1.67*	1.35*	0.31
0.5	1.84	1.69	0.34
1.0	1.61	1.37	0.32
1.5	1.44	1.18	0.31
2.0	1.23	1.00	0.31
2.5	1.00	n.a.	n.a.

* A proportion of roads in this sample typically had unsealed shoulders resulting in lower observed crash risk for the category.
Source: Jurewicz and Zivanovic (2011).

It is noted that roads with no sealed shoulder (0 m in Table B 7) had a lower likelihood of crashes – the reason for this result was not completely clear. It is likely that the roads with no sealed shoulders had a range of unsealed shoulder widths. This would have an effect of lowering the overall relative risk for the 0 m category. Instances of mixed sealed and unsealed shoulders were also present but less common. Since the 0 m category was the different from others, it could be left out of the analysis.

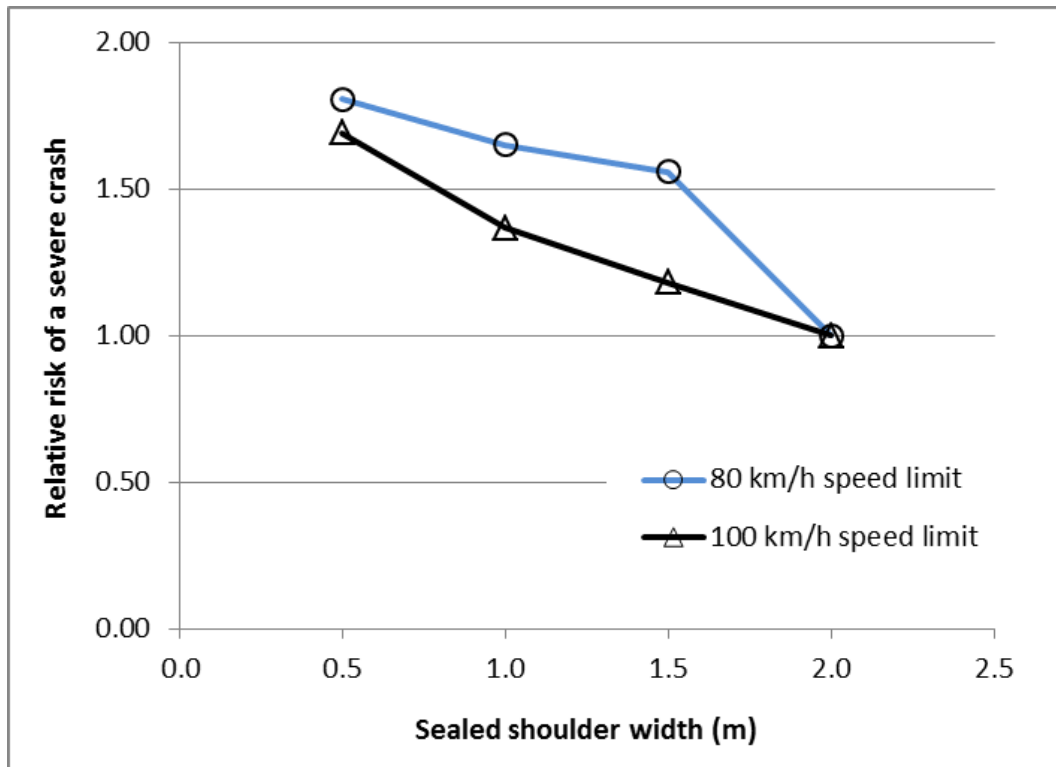
Additional analysis was performed for a similar subset of rural roads, but with a speed limit of 80 km/h. It showed that the provision of sealed shoulders had an even stronger effect in reducing the crash likelihood on these roads, as shown in Table B 8.

Table B 8: Relative risks and severity indices for sealed shoulder widths on single-carriageway rural roads (Queensland, 80 km/h)

Average sealed shoulder width (m)	Relative crash risk	Relative fatal and serious injury crash risk	Severity index
0	1.83	1.73	0.31
0.5	1.92	1.81	0.31
1.0	1.80	1.65	0.30
1.5	1.64	1.56	0.31
2.0	0.84	1.00	0.25
2.5	1.00	-	-

The results for severe crashes have been combined in Figure B 8. The presented relationship is comparable with a recent investigation of rural undivided roads in Victoria (Austroads 2013b).

Figure B 8: Relative risk of severe crashes given different shoulder widths and speed limits (Queensland, undivided rural roads)



Many outer urban roads in Queensland have sealed shoulders utilised as stopping or informal passing lanes at intersections. Analysis of sealed shoulder width was also performed on urban roads. To limit the confounding effects of other variables, the analysis was carried out in two parts – single and dual-carriageway roads. Also, traffic lanes were limited to 3.3–3.5 m widths and speed limits were restricted to typical ranges for each road design stereotype.

Single-carriageway urban roads (60 km/h speed limit) also showed the benefits of providing a sealed shoulder. The results are presented in Table B 9.

Table B 9: Relative risks and severity indices for sealed shoulder widths on single-carriageway urban roads (60 km/h)

Average sealed shoulder width (m)	Relative crash risk	Relative fatal and serious injury crash risk	Severity index
0.5	2.48	3.09	0.21
1.0	1.70	2.75	0.27
1.5	1.18	1.50	0.21
2.0	1.00	1.00	0.17

Source: Jurewicz and Zivanovic (2011).

Dual-carriageway urban roads (70 and 80 km/h speed limits) showed a similar crash risk pattern to single-carriageway roads. The lack of a clear pattern for severe crashes and severity indices on these roads suggests that sealed shoulders only influenced the likelihood of crashes. Table B 10 presents the analysis results.

Table B 10: Relative risks and severity indices for sealed shoulder widths on dual-carriageway urban roads (70 and 80 km/h)

Average sealed shoulder width (m)	Relative crash risk	Relative fatal and serious injury crash risk	Severity index
0.5	1.61	1.00	0.17
1.0	1.47	1.18	0.22
1.5	1.18	1.01	0.24
2.0	1.00	1.01	0.28

Source: Jurewicz and Zivanovic (2011).

Past research into roadside safety, summarised in AASHTO (2010), suggests that wider shoulders provide a greater opportunity for drivers to recover from minor involuntary lane departures. The likelihood of recovery reduces rapidly with the offset from the traffic lane. Thus, provision of excessively wide shoulders is likely to see a progressive reduction in safety benefits.

Further analysis published in Austroads (2011a) and carried out using Victorian data showed that rural roads with no sealed shoulder but with a generous unsealed shoulder generally had better run-off-road casualty crash performance than roads with a narrow sealed shoulder and no unsealed shoulder. The study also quantified the safety benefits of providing an additional unsealed shoulder where a sealed shoulder exists (e.g. through maintenance practices). These results pointed to the importance of good quality shoulder recovery width within the first 4 m of the roadside.

B.11 Parking Lanes

The Queensland crash rates database contained information about the presence of parking lanes on urban arterial roads. Analysis of crash rates by Jurewicz and Zivanovic (2011) was carried out for single and dual-carriageway roads to investigate the effect of providing a parking lane. Table B 11 presents the results.

Table B 11: Relative risks and severity indices of urban roads with and without parking lanes

Road design stereotype	Parking lane	Relative crash risk	Relative fatal and serious injury crash risk	Severity index
Single carriageways (60 km/h only)	Present	1.42	1.02	0.15
	Not present	1.00	1.00	0.21
Dual carriageways (60, 70 and 80 km/h)	Present	1.15	1.27	0.22
	Not present	1.00	1.00	0.20

Source: Jurewicz and Zivanovic (2011).

The analysis shows that on single-carriageway urban roads with a 60 km/h limit, the crash likelihood was substantially increased when a parking lane was present. The difference was negligible for severe crash likelihood, indicating perhaps that the parking lane was contributing to low-severity crashes. Crash likelihood was higher on dual-carriageway roads with parking lanes, especially for severe crashes. This suggests that parking is a more significant risk factor on these roads, which typically have higher speed limits and operating speeds in non-congested periods.

Parking lane analysis was not carried out for rural roads, as parking is not usually significant on these roads.

The above analysis may not be very robust due to many confounding issues with the available data. For example, there was no information about the parking demand and restrictions where a parking lane was present or not present. An evaluation of parking demand and controls with respect to crash performance would be much more meaningful and could be carried out in the future.

B.12 Clear Zones

The effect of roadside design on the safety performance of single-carriageway rural roads was investigated in Austroads (2011a) for 100 km/h speed limit roads in Victoria. One of the key influencing factors on all casualty and severe crashes on rural roads was the available clear zone width. This was due to a large proportion of rural crashes being of run-off-road type. Table B 12 shows that the likelihood of injury crashes of different severities was markedly higher where very little or no clear zone was available (e.g. wall/drop off, trees). This likelihood diminished most significantly in the first 4 m, with very little improvement in wider clear zones. It should be noted that the absolute likelihood of high severity run-off-road crashes (crash rate) was still very high in the presence of wide clear zones in excess of 13 m. The severity of crashes was the highest in the presence of very narrow clear zones.

Table B 12: Relative risks and severity indices for roads with different clear zone widths (100 km/h rural)

Clear zone range	Relative risk of a casualty crash	Relative risk of a fatal or serious injury crash	Severity index
0–2 m	1.97	2.27	0.62
2–4 m	1.29	1.13	0.47
4–8 m	1.00	1.03	0.55
> 8 m	1.00	1.00	0.54

Source: Jurewicz and Zivanovic (2011).

B.13 Hazard Density

The presence of roadside hazards beyond the clear zone varies from site to site. At one location, the roadside will consist of a forest of trees, at another a single row of trees, or there may be a single power pole. The probability of an errant vehicle striking a roadside object is a function of the clear zone and of the 'density' of hazards per unit of roadside length, especially if a vehicle departed the road at a low angle. Understanding the influence of hazard density on crash likelihood may assist in managing roadside hazards more effectively (e.g. were 10 trees more dangerous than a single pole over a 100 m length?).

Austrroads (2011a) investigated the influence of roadside hazard density beyond the available clear zone to the left of the direction of travel, on the likelihood of crashes. Re-analysis of the Austrroads (2011a) data was presented in Jurewicz and Zivanovic (2011) and is presented in Table B 13, which indicates that the likelihood of fatal and serious injury crashes in the direction of travel increased with hazard density on the left. The relationship with all casualty crash likelihood was less clear, except when the hazards were very dense. This re-analysis was controlled for clear zone width as the two variables were negatively correlated.

Table B 13: Effect of roadside hazard density on fatal and serious injury run-off-road crashes

Roadside hazards per 100 m of roadside	Relative risk of a casualty crash	Relative risk of a fatal or serious injury crash	Severity index
< 8	1.20	1.00	0.45
8–5	1.00	1.11	0.60
25–50	1.10	1.16	0.57
> 50 or continuous	1.58	1.73	0.60

Source: Jurewicz and Zivanovic (2011).

These results can be applied to both sides of the road by averaging the relative risk due to hazard density on both sides if the directional traffic flows were about the same.

These results combined with the results from Appendix B.12 indicate that in high-speed environments, the wider clear zones were more important when hazards were closely spaced or continuous (e.g. when a road runs through a forested area or a cutting). Narrower clear zones may be more acceptable when hazards were sparse.

The above research omitted the role of safety barriers given their confounding role in crash likelihood. Ongoing Austrroads research on the role of barriers in roadside safety (Project ST1427, continuation of Austrroads 2011a) provides strong research evidence that flexible barriers deliver significant severe crash likelihood reductions and reduce the typical severity of recorded crashes.

B.14 Horizontal Alignment

Roads with a high number of horizontal curves are associated with a higher crash risk, particularly where motorists travel at inappropriately high approach speeds. Sharp curves are a major risk factor. Austroads (2010f) identified that for curves with radii less than 400–600 m range, the relative risk of a crash increased substantially. Austroads (2010a) carried out analysis of the effect of road curvature on 3000 km of single-carriageway rural roads in Victoria. The higher frequency of curves was found to increase casualty crash likelihood. Additional analysis showed that the frequency of curves had a greater effect on crash likelihood than their relative sharpness, when considered on the basis of long continuous road sections (10 km). A relationship was developed for the relative risk of casualty crashes along a given road section, given the frequency of curves (Equation A5):

$$RR_{\text{cas}} = 0.00055 CF^2 + 0.0246 CF + 1.00 \quad \text{A5}$$

where

CF = the average frequency of curves per 10 km

The frequency of 40 curves per 10 km would increase the risk of a casualty crash by 2.86 compared with a straight road section.

B.15 Terrain

Hilly or mountainous roads have reduced sight distance due to their vertical geometry. Austroads (2010d) presented an example based on New South Wales data showing that the casualty crash rate (i.e. crash likelihood) was approximately 4.5 times higher for rural roads in an undulating terrain than in flat terrain. This factor would be a combination of many other factors presented in previous sections, e.g. curve frequency and clear zone width.

Steeper gradients also lead to increased variability in travel speeds (e.g. heavy vehicles travel slower uphill), which is a risk factor for crashes. Motorist speeds may be unintentionally high on downhill slopes, leading to loss of control; therefore, steep slopes present a higher risk to motorists. Jurewicz and Zivanovic (2011) analysed the effect of grade on the risk of run-off-road crashes on single-carriageway rural roads with a 100 km/h speed limit in Victoria. They reported that the relative severe crash likelihood increased with grade, especially for steep grades over 6%.

B.16 Intersection Control

Austroads (2010d) provided information relating to casualty crash rates for different intersection types across several Australian jurisdictions. The Victorian crash data from this project, based on the 2001–05 period, was re-analysed to provide relative risk factors for fatal and serious injury crashes. Only intersections of state roads were included in the analysis. The results are presented in Table B 14. The environment field was based on the provided road inventory and is generally indicative of the speed environment (i.e. higher speeds in rural environment). The lowest severe crash rate was for 3-leg rural roundabouts; hence, this was the benchmark (relative risk of 1.00)¹⁵. Other relative risk values confirmed that roundabouts were generally the safest form of intersection control, followed by traffic signals and stop/give-way signs. Four-leg intersections generally had a higher level of crash risk.

¹⁵ The urban 4-leg roundabout had the lowest relative risk of a severe crash, but the sample size of sites was small and the result should not be considered robust.

Table B 14: Relative risk factors for severe crashes at different intersection types

Environment	Number of legs	Intersection type		
		Roundabout	Traffic lights	Stop/give way
Rural	3	1.00	1.85	3.34
	4	1.66*	2.83	4.68
Urban	3	1.17	2.02	2.68
	4	0.84*	2.30	1.48*

* These results were based on a sample of less than seven sites, hence were likely to carry a greater standard error than other results.

Source: Based on Austroads (2010d).

The results for the stop/give-way intersection type were confounded by a variety of different design scenarios. Closer inspection of the data showed that this group included typical rural stop/give-way intersections, acceleration lanes, and intersection slip lanes observed more frequently in the urban environments. Freeway ramps were excluded from the analysis.

In the context of this report, the two highest severe crash risk factors in Table B 14 were for rural unsignalised intersections and for rural signalised cross-intersections. This confirms and extends the focus of the objectives stated in the introduction in Section 1, which identifies such intersections as higher-risk.

B.17 Other Factors

There are many other road features and risk factors that influence the likelihood and severity of crashes, which were, or could be, considered for inclusion in speed limit guidelines. Some are specific to individual locations; others are more relevant indicators of safety at a road section or route level. Many of these were not included in this report due to lack of appropriate evidence or data for analysis; some examples that were investigated include:

- presence of protected right-turn lanes
- traffic composition, i.e. proportion of heavy vehicles and motorcyclists
- level of accommodation of different road users, e.g. pedestrian crossing control where pedestrians are present, overtaking lanes where the proportion of heavy vehicles is high, segregated bicycle facilities
- overall pavement quality along the road, especially with respect to skid resistance and roughness.

These factors could be considered as advisory in risk-based speed limit setting. Information about their impact on crash likelihood and severity should be sought from updated literature or future data analysis.

Appendix C Examples of Higher-risk Roads

C.1 High Pedestrian Activity Zones

Commercial areas where there are high numbers of pedestrians during the day may warrant a part-time speed limit reduction during the times with high risk, i.e. when there are a large number of pedestrians crossing the road. These areas include:

- school zones
- strip shopping centres/commercial areas
- urban areas with on-street parking
- central business districts
- public transport interchanges (e.g. tram stops, rail and bus terminals).

C.2 High-volume Outer Urban Arterials

Where traffic is approaching from a high-speed environment (freeway or rural road) into an urban area, the large speed differentials between these two areas present a high risk.

Research has shown that the presence of major shopping complexes, hotels, tertiary institutions, and sporting complexes are a risk factor for pedestrian and cyclist crashes in outer metropolitan areas. This was based on an unpublished study of pedestrian and cyclist crash data from NSW, Victoria and Queensland, combined with site investigations of high crash locations.

Ma et al. (2010) studied urban arterial road segments in Beijing with speed limits between 50 km/h and 70 km/h. The speed limits were classified as high (70 km/h), medium (60 km/h) and low (50 km/h). The report concluded that the high and medium speed limits contributed significantly to the number of severe crashes.

C.3 Transition Between Speed Environments

SWOV (2010) reported that motorists often fail to decelerate sufficiently when transitioning from one speed environment to another, where the road environment dictates a lower speed is necessary. These were higher-risk locations due to the considerable reduction in driving speed required. Some examples were:

- travelling from a motorway to a rural road
- on a rural road, a long section of straight road followed by a series of bends
- a high-speed rural road into an urban area.

Physical speed limiters were used in these transitional situations to assist drivers to adapt their speed better to the road conditions. Some examples were installation of a roundabout at the end of the motorway off-ramp, and use of gateway treatments before entering an urban area.

C.4 Tourist or Motorcycle Routes

Tourist routes have many motorists who are unfamiliar with the road conditions, and may perform unusual traffic manoeuvres; therefore, these road sections are high risk. Sometimes time-based speed limits are applied to seasonal tourist destinations; e.g. in New Zealand.

A trial undertaken on the Great Ocean Road in Victoria, a major tourist route, involved speed limit reductions and road infrastructure improvements. The road features frequent changes in horizontal and vertical alignment, narrow lane width and roadside hazards, which all contribute to increased crash risk. The road also has a motorcycle crash problem.

C.5 Uncontrolled Rural Intersections

In Australia, most rural intersection casualty crashes occur at uncontrolled intersections (58% of rural intersection crashes for the period 1999–2003).

Austrroads (2010b) reported on rural intersection crashes in New Zealand in 2003. A large proportion of these crashes resulting in fatalities occurred at uncontrolled intersections (48%) compared to intersections with give-way or stop signs; therefore, these uncontrolled intersections were considered higher-risk locations.

Installation of give-way or stop signage would reduce the risk at uncontrolled rural intersections by making it clear who has priority. Different estimates have been given for the estimated crash reduction of installing signage at uncontrolled intersections:

- Austrroads (2009a) reported that installing signs (give-way or stop signs) results in a 30% reduction in adjacent-approach crashes.
- Creasey and Agent (1985) reported that the installation of intersection-related warning signs in rural areas could reduce crashes by 40%.

C.6 At-grade Railway Crossings

Speed limits at rural level crossings on sealed roads in Victoria were reduced from 100 km/h to 80 km/h in 2007. This speed limit reduction was introduced after a truck crashed into a train at Kerang in 2007, killing 11 people.

Speed management infrastructure can be installed on the approach to rail crossings. An example is transverse rumble strips, which has been shown to result in a 4–5 km/h mean speed reduction (Austrroads 2010a).

C.7 Narrow Bridges

Ivey et al. (1979) reported on hazardous highway bridges in the USA, and developed a Bridge Safety Index (BSI) and a Priority Index (PI). The BSI took into account the most important factors such as bridge lane width, approach sight distance, grade continuity, shoulder reduction, volume, traffic mix/composition and roadside activity; while the PI related to the traffic volume on the road section. The study showed that most motorists recognised the risk associated with a narrow bridge and lowered their speed (and lateral movement) when approaching a bridge. The report recommended combinations of treatments, such as the use of early warning signage, bridge delineation, and crashworthiness of rail structures.

Giummarra (2003) developed a methodology to identify bridges with a high risk profile. A relative risk score for individual bridges was calculated by considering a number of physical and crash-risk factors, such as:

- physical factors: bridge condition, presence of barriers, pedestrian guardrails, bridge width, sight distance, guideposts and delineation
- crash history and severity.

The methodology was successfully trialled on a sample of bridges in various regions of Australia.

C.8 Freeways

Reducing speed limits during times of congestion was shown to reduce the number of vehicle-to-vehicle incidents on urban motorways in the UK and the Netherlands (Austrroads 2010e). This is believed to occur due to reduced speed differentials between vehicles. This was demonstrated by the UK managed motorways scheme.

C.9 Rural Unsealed Roads

Studies in Australia, New Zealand and Sweden have found that crashes on unsealed roads were generally more common per vehicle kilometre than on equivalent sealed roads (Austroads 2010c).

Unsealed roads often have a hazardous road environment, including poor road geometry, poor sight distance, uncontrolled intersections, and inadequate delineation (Austroads 2010c). Crash risk is increased due to a combination of factors such as excessive speed, drink driving, low levels of restraint use, fatigue, and driver inexperience on unsealed roads.

Dissanayake and Liu (2011) reported on a study undertaken in Kansas comparing two gravel roads with similar characteristics in different counties, which had differing speed limits. One county had posted speed limit signs with 35 mph (56 km/h), and the other had a statutory (default) speed limit of 55 mph (88 km/h). By comparing speed and crash data, they concluded that lowered posted speed limits on gravel roads did not assist in improving safety or result in any significant difference in operating speeds.

Analysis by Jurewicz and Zivanovic (2011) of single-carriageway, 100 km/h rural roads in Queensland determined that the unsealed roads had a severe crash risk 2.53 times higher than sealed roads.

The Kingborough Safer Speeds (KiSS) Demonstration evaluated the effects of reducing the speed limit from 100 km/h to 80 km/h on gravel roads (Langford 2010). The evaluation showed that there were fewer vehicles travelling at 70 km/h or more on gravel roads, and there was a 4 km/h reduction in mean free travel speeds on gravel roads. Due to the small crash numbers on gravel roads, which remained unchanged two years after the trial, the effect of the lower speed limit on casualty crashes was not fully evaluated at the time of writing.

Appendix D Access and Intersection Density Assessment

The following methodology was applied to calculate the average number of standard vehicle accesses per 100 metres based on driveways, business access points, minor and major intersections. This method has been applied consistently in VLimits 2.0 (www.vlimits.com.au), QLD-SLR ([www.qlimits.com.au](http://www qlimits.com.au)) and WALIMITS 3.0 (walimits.webpage.com.au).

The total number of accesses is counted on both sides of the road for the full length of the section being reviewed. Crossroads are counted once on each side of the road. Each type of access is weighted as per Table D 1 to convert it to equivalent standard driveways. The total is summed and divided by the road section length in kilometres x 0.1.

Table D 1: Access and intersection weighting

Access category	Weighting
Residences, small commercial establishments, small public buildings and other units that generate light and/or occasional activity.	1
Average commercial establishment, local schools, caravan parks, light industries, public buildings and units generating activity, which is either: <ul style="list-style-type: none"> ▪ continuously light ▪ moderate at certain times, such as commuting hours ▪ substantial at infrequent intervals. 	2
Heavy industry, schools, shopping centres and other units generating continuous moderate activity or substantial activity at certain regular times.	3
Large shopping centres and other units generating substantial and continuous activity. Some large industries, which are tourist attractions or for some other reason generate substantial traffic volumes, would be included in this activity.	4
Unsignalised intersecting roads of substantially lesser importance than the road being assessed, or intersecting roads where side traffic and turning movements have little effect on the traffic flow pattern of the road being considered.	1
Unsignalised intersecting roads of lesser importance than the road being assessed but where the side-road traffic and turning movements are such that the intersection has an appreciable effect on the traffic flow pattern of the road being considered.	2
Unsignalised intersecting roads of comparable or greater significance than the road being assessed. Intersections that have a pronounced effect on the traffic flow pattern of the road being considered.	3
Roundabouts, signalised intersecting roads and any at-grade rail crossings.	3

Generally, only active access points are included, i.e. those which show signs of current use. Disused or duplicated access points in rural or urban fringe areas should not be included in the calculations. In areas where rapid development is occurring, known access points to the land parcels about to be developed may be included in the calculations.

It should be also noted that:

- abutting development on service roads is not considered and therefore only the points of access to the through traffic lanes are counted
- crossroads are counted only once on each side of the road being assessed, i.e.
 - stem of a T or Y intersection – 1 access point
 - cross-intersection – 2 access points
 - any multi-leg intersection – 2 access points
- grade separated intersections may be ignored; however, each ramp on or off the assessed road should be counted
- if the assessed road section begins or terminates as a stem of a T-intersection, that intersection should not be counted
- for divided roads, the presence of the median while calculating the number of accesses can be ignored.



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