High-risk rural roads guide

This document provides guidance on the government's Safer Journeys 2020 Strategy initiative to focus efforts on high-risk rural roads.

Safer Journeys

New Zealand Government

High-risk rural roads guide
September 2011

NZ Transport Agency
Published September 2011

ISSN 978-0-478-38039-2 (print)
ISSN 978-0-478-38038-5 (online)

National Office
50 Victoria Street
Private Bag 6995
Wellington 6141
New Zealand

T 64 4 894 5400
F 64 4 894 6100

Foreword

Crashes on rural roads are a serious issue in New Zealand. The social and economic costs are high. The government's road safety strategy Safer Journeys signals that more must be done to improve safety on our high-risk rural roads. Crashes on rural open roads (state highways and local roads with speed limits of 80km/h or more) accounted for 53% of New Zealand's fatal and serious road crashes for the five-year period to 2009.

The vision of Safer Journeys is *'a safe road system increasingly free of death and serious injury'*. The strategy gives us a road map for focusing our efforts where the greatest gains can be made. Roads and roadsides are an area of great concern, and high-risk rural roads are identified as requiring early action under the strategy.

Safer Journeys introduces the Safe System approach, which represents a fundamental shift in the way we think about, and act on, road safety. Human beings make mistakes and crashes are inevitable, but in a safe system they are less likely to result in death and serious injury.

This *High-risk rural roads guide* is a flagship Safer Journeys initiative. It is a practical guide to making our roads safer, intended for use by all road controlling authorities that manage high-risk rural roads.

The guide introduces a new way to identify high-risk road sections and, using the Safe System approach, provides best practice guidance on choosing effective countermeasures.

Our traditional approach to road safety has helped achieve our current good levels of road safety. We now need to add to this mix the Safe System approach, where road designers and users share responsibility for a system to protect road users from death and serious injury.

A draft guide was issued in May. Many supportive comments and helpful suggestions were received and have been incorporated into the release of this guide. We see the guide as a living document so it's important that we keep it up-to-date. We are only beginning our journey to understand what safe system thinking means for the future of New Zealand roads. As new countermeasures are developed and trialled, and we gain more experience with the use of the guide and the Safe System approach, we intend to revise the guide.

If you are involved in managing a rural road network, I encourage you to consider how applying the *High-risk rural roads guide* can change for the better what you do. Your experiences and suggestions will be most welcome.

Geoff Dangerfield
Chief Executive
NZ Transport Agency

Contents

Glossary of terms

3 Es	engineering, education and enforcement
AADT	annual average daily traffic
ATP markings	audio-tactile profiled markings
Austroads	National Association of Australian Road Authorities
CAS	Ministry of Transport's Crash Analysis System
CMS	changeable message sign
EMP	edge marker post
gTKP	global transport knowledge partnership
Harm minimisation speed	posted speed limit targets that are based on impact speeds at which the chance of a fatal outcome increase rapidly
Harm reduction speed	a posted speed limit based on using a balance between the current speed limit and a harm minimisation speed
high-severity crashes	fatal and serious crashes
HRRR	high-risk rural roads
IL	investigation levels for skid resistance
iRAP	International Road Assessment Programme
KAT	KiwiRAP assessment tool
KiwiRAP	The New Zealand joint agency Road Assessment Programme
LoS	level of service
MoT	Ministry of Transport
NMA	Network Maintenance Area
NSC	Network Safety Coordination
NZTA	NZ Transport Agency
OECD	Organisation for Economic Co-operation and Development
PIARC	World Road Association
RCA	road controlling authority
RISA	Road Infrastructure Safety Assessment
RoNS	road of national significance
RPS	road protection score
RRPM	retro-reflective raised pavement marker
SAWS	speed-activated warning signs
SCRIM	Sideway-force Coefficient Routine Investigation Machine
SHGDM	*State highway geometric design manual*
speed zone	a posted speed limit based on the driver's 85th percentile operating speed
SWOV	Dutch national road safety research institute
TERNZ	Transport Engineering Research New Zealand
the guide	the *High-risk rural roads guide*
TCR	Traffic Crash Reports (completed by the Police and coded by the NZTA)
TA	territorial local authority
VMS	variable message sign
WRB	wire rope barrier

1 Introduction and objectives

1.1 Purpose

The *High-risk rural roads guide* (HRRRG or 'the guide') has been prepared by the NZ Transport Agency (NZTA) to provide guidance on the government's Safer Journeys 2020 Strategy initiative to focus efforts on high-risk rural roads.

The objective of the guide is to provide practitioners with best practice guidance to identify, target and address key road safety issues on high-risk rural roads. The guide provides links to a number of road safety resources and guidance for planning, funding and evaluating safety projects and programmes.

The guide focuses on the Safer Journeys actions. However, roads that have crash problems but do not meet the criteria for a high-risk rural road may still warrant investigation and the use of suggested countermeasures but may not be prioritised in terms of funding.

Specifically, the guide is intended to provide:

- details of a Safe System approach to Safe Roads and Roadsides and to a lesser degree Safe Speeds in New Zealand (two of the four key components of a Safe System)
- a discussion of key crash issues on New Zealand rural roads
- tools to help identify and analyse high-risk rural roads
- a range of countermeasures for key crash types occurring in rural environments, to help develop best-value remedial treatments
- guidance for developing, prioritising and funding road safety infrastructure and speed management programmes
- references to further tools and resources to evaluate implemented countermeasures.

The guide has also been developed to provide national consistency regarding the identification of high-risk rural roads and the application of proven countermeasures.

The guide provides a mechanism for road controlling authorities (RCAs) to manage the safety of their road networks. Although there are many ways in which high-risk rural roads can be identified, regions will still need to identify and prioritise their own issues regardless of whether they conform to those identified in the guide. Guidance on funding is discussed in section 2.4.

In addition to this guide, for more detailed information and recommendations on both high-risk urban and high-risk rural intersections, refer to the *High-risk intersection guide.* For more detailed information on motorcyclist issues and treatments refer to the *High-risk motorcycle guide.*

1.2 Scope

The guide supports and references:

- the New Zealand Ministry of Transport's (MoT) Safer Journeys 2020, New Zealand's Road Safety Strategy 2010–2020 (March 2010)
- the Safer Journeys Implementation Action Plan 2011/12 (May 2011)
- the NZTA's Road Safety Strategic Plan (updated in April 2011)
- New Zealand legislation and, in particular, the Land Transport Act 1998 and rules made pursuant to that act, including the Land Transport (Road User) Rule, the Land Transport Rule: Traffic Control Devices, and the Land Transport Rule: Setting of Speed Limits
- Austroads Guides (Guides to Traffic Management, Road Design, Road Safety) and other Austroads Technical Guides
- New Zealand and, as appropriate, Australian standards, codes of practice and guidelines
- published standards of various organisations and authorities.

The guide provides direction on measures to improve safety on high-risk rural roads. However, practitioners should always apply sound judgement when identifying and installing any countermeasures to ensure the best possible safety outcomes. The principles behind any departures from recommended practice should be documented.

1.3 Target audience

The principles presented in the guide are relevant to rural roads in both the state highway network and the territorial local authority (TA) network. The HRRRG is intended to provide guidance to a range of technical practitioners, including:

- those from RCAs
- state highway and local roads engineers
- planners
- funders.

It may also be useful to other industry practitioners, developers and private landowners when they would like to identify road safety risks and develop appropriate risk-reducing measures.

1.4 Risk management

The objective of this guide is to reduce fatal and serious injuries on the New Zealand rural road network as defined by the Safer Journeys strategy. The term 'high-risk rural road' takes into account both consequence and likelihood of fatal and serious crashes occurring.

In defining a high-risk rural road this guide provides a mixture of information (refer section 4) ranging from providing actual locations of high-risk rural roads (through published KiwiRAP risk maps) and the methodology to assist RCAs in risk identification (such as those calculations and charts provided for local roads to determine high-risk routes etc).

It is important to note that communication and consultation is one of the most important components of risk management and should be considered at all stages of the process. For example in using the high-risk rural road definitions (which use actual and predicted risk) further risk identification may be through public feedback, Road Transport Associaton, high-volume road users, AA, emergency services etc. In using this feedback we should therefore also determine whether that level of perceived risk matches the actual or potential risk through the use of crash and road data. Once routes have been determined, further consultation can be undertaken with the community and road user groups on better understanding the risks, and the best methods of addressing these. This is explained further in sections 5 and 7.

The user of this guide should document the identification, analysis, treatment and monitoring process for high-risk rural roads. This is an important means of recording the right level of information for the decision maker and the person responsible for taking action.

Further information on risk management, communication and consultation and recording the risk management process can be sourced from AS/NZA ISO31000: 2009 Risk Management – Principles and Guidelines and chapters 3 and 9 of SAA/SNZ HB 436:2004 Risk Management Guidelines.

1.5 Definitions

In this guide:

- a rural road is a motorway, state highway, expressway, local road or private road with a speed limit of 80km/h[1] or more
- a high-risk rural road[2] is classified as:
  - a rural road where the fatal and serious crash rate (personal risk) or crash density (collective risk) is high or medium–high compared with other roads as defined in section 4 and/or
  - a rural road with a high or medium–high collective risk; or a high or medium–high personal risk (as defined by KiwiRAP[3]) and/or
  - a rural road that has engineering features that have the potential for fatal or serious injury crashes to occur as determined by the KiwiRAP star rating or road protection score (RPS), eg a road with 1 or 2 stars or an RPS greater than 10 (section 4) and/or
  - a rural road that has a personal risk of greater than 2.5 identified as part of the Road Infrastructure Safety Assessment (RISA) process (section 4)
- any section of road to be classified as a high-risk rural road must have an actual crash record of 3 or more fatal and serious crashes over 5 years or 5 or more fatal and serious crashes over 10 years or similar number of predicted high-severity crashes using KiwiRAP star rating, RPS and RISA models above (see figures C-1 and C-2 in Appendix C).

1 Note that, for the purposes of the guide and any relevant crash analysis, the definition of a rural road is a road with a posted speed limit of 80km/h or more. However, in some documents, such as the New Zealand *Traffic control devices manual*, this has been defined as being 70km/h or more.[2]

2 A rural road identified as high-risk through this guide may not necessarily meet the requirements for a high strategic fit in the Investment and Revenue Strategy for funding purposes. Refer section 2.4 and 4.1.

3 KiwiRAP is New Zealand's joint agency Road Assessment Programme. [3] The Ministry of Transport, the NZTA, Police, ACC and AA developed the programme to assess the risk of New Zealand roads and targeted it at decision makers and the wider public.

1.6 Structure of the document

The guide is divided into seven main sections :

Section 2	Strategic context	Outlines the varying strategies and priorities of the government. It includes descriptions and background information on the Safer Journeys strategy and the Safe System approach.
Section 3	Crash priorities	Discusses the focus on key crash types across all rural road networks.
Section 4	Identifying high-risk rural roads	Describes the types of data and resources available to identify high-risk roads, includng resources that are crash data driven and those that involve a risk-based assessment. It includes guidance for preparing forward works programmes, examples of high-risk rural roads and how this document and analysis fits in with Safety Management Systems (SMSs).
Section 5	Understanding the issues	Describes what further analysis could be undertaken to better determine the safety problem and the most appropriate countermeasures.
Section 6	Countermeasures	Includes the treatment philosophy, summaries of countermeasures, examples of types of countermeasures, reference material, the implementation process and best practice across networks.
Section 7	Programme implementation, monitoring and evaluation	Describes the processes involved with prioritising and programming works identified as part of the methodology. Provides advice on how best to monitor and evaluate completed countermeasures at high-risk sites and routes.
Section 8	Other information sources	Includes other sources of information that have been included in the development of this guide and provide additional guidance to RCAs in developing and treating high-risk rural roads. References throughout the document are provided in brackets [ref no.]

2 Strategic context

2.1 Safer Journeys – Road Safety Strategy 2010

The New Zealand government released its Safer Journeys – Road Safety Strategy in March 2010. Safer Journeys is a national strategy to guide improvements in road safety over the period 2010–2020. The strategy sets out a long-term vision for New Zealand of 'a safe road system increasingly free of death and serious injury'.[4]

4 References noted by a number in brackets [..] can be found in section 8 'Other information sources'.

To support the vision, Safer Journeys introduces, for the first time in New Zealand, a Safe System approach to road safety (section 2.2).

Safer Journeys also lists a number of key initiatives that have been identified as having the greatest impact on road trauma. These initiatives will be implemented through a series of action plans relating to the four key components of a Safe System – Safe Roads and Roadsides, Safe Speeds, Safe Road Use and Safe Vehicles.

2.2 Safe System

2.2.1 Safe System principles

A Safe System approach to road safety represents a fundamental shift in the way New Zealanders think about road safety. It works on the principle that it is not acceptable for a road user to be killed or seriously injured if they are involved in a crash. The Safe System approach also acknowledges that road users are fallible and will continue to make mistakes.

Scandinavian research [4] indicates that, even if all road users complied with all road rules, fatalities would only fall by around 50% and serious crashes by 30%. Putting this in a New Zealand context, if everybody obeyed all the road rules, there would still be around 200 road deaths each year (based on current fatalities).

The traditional 3 Es approach to road safety – engineering, education and enforcement – has helped achieve our current good levels of road safety. These elements remain important, but the traditional approach tends to blame and try to correct the road user. Continuing with this approach will not achieve the desired gains in road safety in New Zealand. A Safe System approach recognises the need for system designers and road users to share responsibility, with the ultimate aim of protecting road users from death and serious injury.

The Safe System approach acknowledges these four principles:

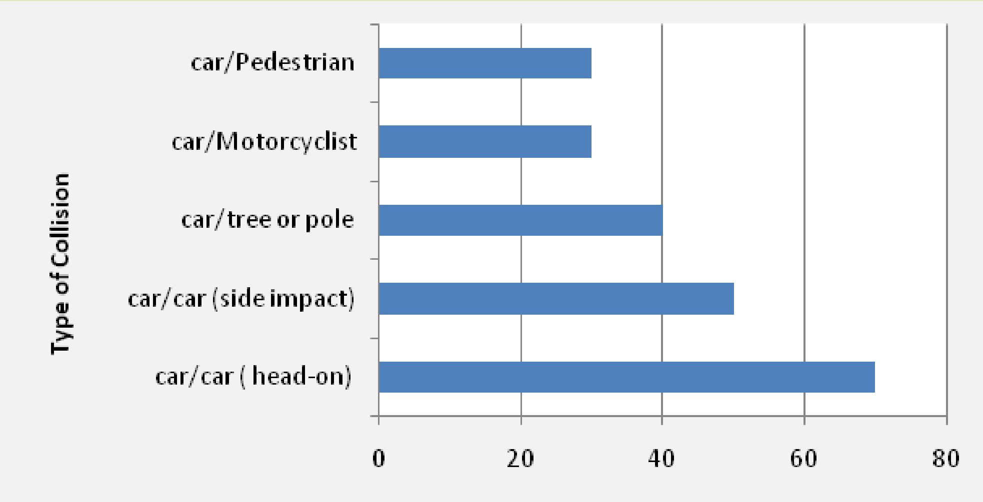
Human beings make mistakes and crashes are inevitable	However, the current consequences of those mistakes and crashes should not be regarded as acceptable. A Safe System aims to reduce the likelihood of crashes with a focus on removing the potential for death or serious injury.
The human body has a limited ability to withstand crash forces	A Safe System aims to manage the magnitude of crash forces on the human body to remove the potential for death or serious injury (refer to figure 2-1).
System designers and road users must all share responsibility for managing crash forces to a level that does not result in death or serious injury	The aim of the system designer is to deliver a predictable (self-explaining) road environment to the road user that is also forgiving of mistakes. The Safe System relies on the principle of shared responsibility between system designers and road users. System designers include planners, engineers, policy makers, educators, enforcement officers, vehicle importers, suppliers, utility providers, insurers, etc.
It will take a whole-of-system approach to implement the Safe System in New Zealand	Everyone plays a part in providing a safe transport system. Road designers will design safe roads and roadsides that will encourage safe behaviour and be forgiving of human error. Vehicle technology (safe vehicles) will vastly improve communication with the road environment to ensure appropriate speeds that respond to real time conditions (safe speeds). Road users need to understand and play their part in the system, including an acceptance of the skills required to get a driver licence as well as maintaining their vehicles to appropriate standards.

2.2.2 Human tolerance to physical force

The fundamental principle of a Safe System is the relationship between road users, vehicles, speeds and road infrastructure, and how much force the human body can withstand when each of these four elements interacts in the event of a crash. The OECD [5] states that 'the human body's tolerance to physical force is at the centre of the Safe System approach'. In addition, the Australian Road Safety Strategy (2011–2020) states that 'the chances of surviving a crash decrease rapidly above certain impact speeds, depending on the nature of the collision' [118]. This is illustrated in figure 2-1, which shows the threshold speeds above which the risk of death or serious disabling injury climbs rapidly for five key crash types.

The OECD (2008) recognises that safe speeds are paramount in achieving a Safe System. However, achieving safe operating speeds on rural roads throughout New Zealand will in some cases adversely affect transport efficiency. Other measures, such as providing median separation, would be needed to reduce crash severity where safe speed thresholds cannot be appropriately provided. The need to balance efficiency and safety often leads to compromises in the management of speeds (a harm reduction philosophy as opposed to a more rigid harm minimisation philosophy–see appendix D, section D7).

FIGURE 2-1 Survivable impact speeds for different scenarios ([118 – figure 7])



Note: The range of impact speeds for each crash type is considered to be survivable in most cases. [118 figure 7]

2.2.3 Safe System cornerstones

Under a Safe System, designers create and operate a transport system where road users who are alert and compliant are protected from death and serious injury. The four key cornerstones of a Safe System are illustrated in figure 2-2 and include:

- safe roads and roadsides
- safe speeds
- safe vehicles
- safe road use.

FIGURE 2-2 **The Safe System**

SAFE ROADS AND ROADSIDES are predictable and forgiving of mistakes – their design should encourage appropriate road user behaviour and speeds

SAFE SPEEDS suit the function and level of safety of the road – road users understand and comply with speed limits and drive to the conditions

SAFE VEHICLES help prevent crashes and protect road users from crash forces that cause death and serious injury

SAFE ROAD USE ensures road users are skilled, competent, alert and unimpaired, and people comply with road rules, choose safer vehicles, take steps to improve safety and demand safety improvements

How is the Safe System approach different?

When the driver of a vehicle travelling on a rural road in wet weather loses control on a bend, a crash into a solid roadside object such as a power pole is likely to result in death.

Under a Safe System, the road user has a much lower risk of death or serious injury because:

- vehicles will increasingly have advanced safety features, including electronic stability control (ESC), front and side airbags, and head restraints
- road surfaces will be improved and roadside objects removed or barriers installed
- speed is managed to safe levels through more appropriate speed limits, self-explaining roads that encourage safe speeds and devices such as Intelligent Speed Assist
- road users are alert and aware of the risks and drive to the conditions.

Source: *NZ Herald* (21 December 2006)

2.3 Key Safer Journeys initiatives

2.3.1 Introduction

The Safer Journeys strategy contains road safety initiatives across the four Safe System cornerstones. This guide provides direction on how to implement a number of the key initiatives for Safe Roads and Roadsides and Safe Speeds (to a degree[5]). Specifically, the guide provides information and guidance on the following action under the Safe Roads and Roadsides plan:

> *'Focus safety improvement programmes on high-risk rural roads and high-risk urban intersections'*

Guidance is also provided on a number of speed management initiatives presented under the Safe Speeds plan, including:

> *'Create more speed zones on high-risk rural roads to help make roads more self explaining, and to establish criteria for what roads with different speed limits should look like'*

Speed management is an important way to improve the safety of high-risk rural roads and is therefore included in the guide, alongside typical infrastructure improvement measures.

5 Although only minimal information is provided on speed management a review of speed limit setting is currently being undertaken that will result in the development of a *Speed limits guide* within the NZTA's *Traffic control devices manual.*

2.3.2 Safe Roads and Roadsides

'Focus safety improvements on high-risk rural roads…'

The greatest safety gains on high-risk rural roads are expected to be achieved by focusing on reducing fatal and serious outcomes on key crash types. This approach is also consistent with the Safer Journeys long-term vision:

'A safe road system increasingly free of death and serious injury'

For instance, around 8 out of 10 fatal and serious crashes on the nation's state highways occur on rural roads and, of those state highway crashes, 85–90% of fatal and serious crashes are due to one of three crash types:

- run-off road (on a curve or straight)
- head-on
- at intersections.

Detailed information on these crash types, for both state highways and local roads, is included in section 3.

The NZTA and local government need to ensure that road safety efforts focus on these key areas to help achieve Safe Roads and Roadsides.

2.3.3 Safe Speeds

Safe Speeds is closely linked to Safe Roads and Roadsides – especially for rural road and highway networks. The guide describes how Safe Speeds can be achieved to complement Safe Roads and Roadsides in order to improve safety for all road users. Appropriate speed management-related countermeasures are proposed that relate to all aspects of the Safe System, ie Safe Roads and Roadsides, Safe Road Use, Safe Speeds and Safe Vehicles.

When a driver exceeds the speed limit there is a large increase in the risk of a severe crash. Kloeden studied crashes in South Australia and showed that compared to travelling at the speed limit, the risk of a serious casualty crash doubles at just 5km/h above the limit on 60km/h urban roads or 10km/h above the limit on rural highways.

Figure 2-3 shows the effect of changes in the mean speeds of all vehicles in a rural traffic stream on the number of casualties. Changes in mean speeds have the most effect on the most severe casualties. Nilsson proposed the power relationships in 2004 and Elvik updated and refined them in 2010 using more recent data.

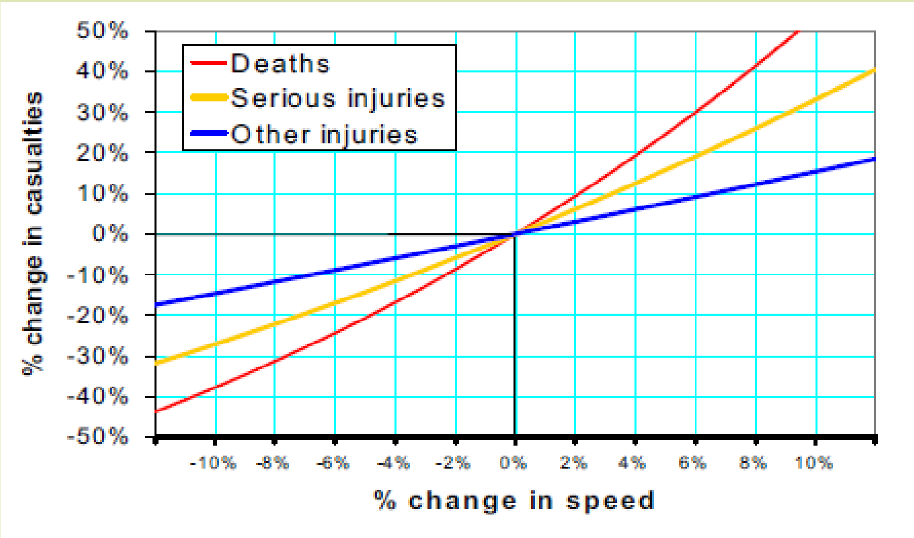
The default speed limit on New Zealand's open/rural roads is 100km/h and it is generally applied to all rural roads with only limited exceptions at the present time. A more suitable speed limit for these roads might in future be one that more closely matches the design speed and the safety features present. The NZTA recognises that there is some merit in applying a safer operating speed limit or speed zone[6] for roads on which the standard rural speed limit is inappropriate. This is further described in appendix D, section D7.

Harm minimisation and harm reduction speeds are used in Safe Systems to reduce high-severity crashes. These are discussed in the countermeasures section in appendix D, section D7.

The Safer Journeys strategy refers to other speed management initiatives, such as speed cameras, lower speed limits in urban areas, self-explaining roads, GPS-based speed advice systems and road improvements to address speed-related crashes.

6 A speed zone takes into account the alignment of a route or section of road and operating speed of vehicles. This is in contrast to the current (as at 2011) method of setting speed limits, which is based primarily on the amount of frontage development.

FIGURE 2-3 Relationship between change of mean speed and casualties on rural roads



Source [118 - figure 6]

2.4 Investment framework

The Government Policy Statement on Land Transport Funding 2012 (GPS), covering the period 2012/13 to 2021/22, has a strong safety focus, with its three priorities being road safety, value for money and economic growth and productivity improvement. While no specific safety funding activity class has been created, there is an expectation that the level of safety investment is to be made transparent and the NZTA will be required to report on how it has been used to improve road safety. Safety expenditure includes the safety proportions of RoNS, safety improvements such as barriers and realignments, minor safety works, efforts on high-risk rural roads and high-risk intersections, motorcycle black routes, demonstration projects, road safety education and a safety component of maintenance and renewals.

The NZTA's Investment and Revenue Strategy (IRS) gives effect to the GPS 2012. The Strategy has a focus on reductions in deaths and serious injuries and the adoption of a 'safe systems' approach in line with Safer Journeys. The 'high strategic fit' assessment of the Strategy includes the 'potential to significantly reduce the number of crashes involving death and serious injuries in line with Safer Journeys on a high-risk rural road'. However at this stage for a 'high strategic fit' the IRS has a requirement to address actual crash records only. A predicted crash rate will be assigned a 'medium strategic fit'. For more details on applying this criteria when developing programmes, refer to the NZTA's Planning, programming and funding manual.

This investment focus combined with this guide is aimed at strongly encouraging RCAs to focus their efforts on the Safer Journeys priorities and actions,

2.5 Source material

The guide recognises the availability of several other high-risk rural roads guidance documents and web-based tools to apply relevant countermeasures. These are described in section 8.

3 Crash priorities

Prioritising safety improvement measures for high-risk rural roads requires a focus on reducing the number of fatal and serious casualties; this involves specifically focusing on the three key types of crashes on rural roads: head-on crashes, run-off-road crashes and intersection crashes (see figure 3-1). Details of crash severity, road type and key crash types within a New Zealand context are further described in this section.

FIGURE 3-1 Crash priorities

Safer Journeys 2020 Road Safety Strategy

'Focus safety improvement programmes on high-risk rural roads and high-risk intersections'

↓

Priority crash types (targeting high-risk rural roads and high-risk intersections)

Head-on crashes | Run-off road crashes | Intersection crashes

3.1 Crash severity on New Zealand's rural road networks

Rural (open road) crashes[6] accounted for 25% of all reported motor vehicle crashes on New Zealand roads over the five-year period 2005–2009. Approximately 30% of injury crashes on all rural roads are recorded as fatal or serious, which would contribute to a large portion of the social cost of crashes.

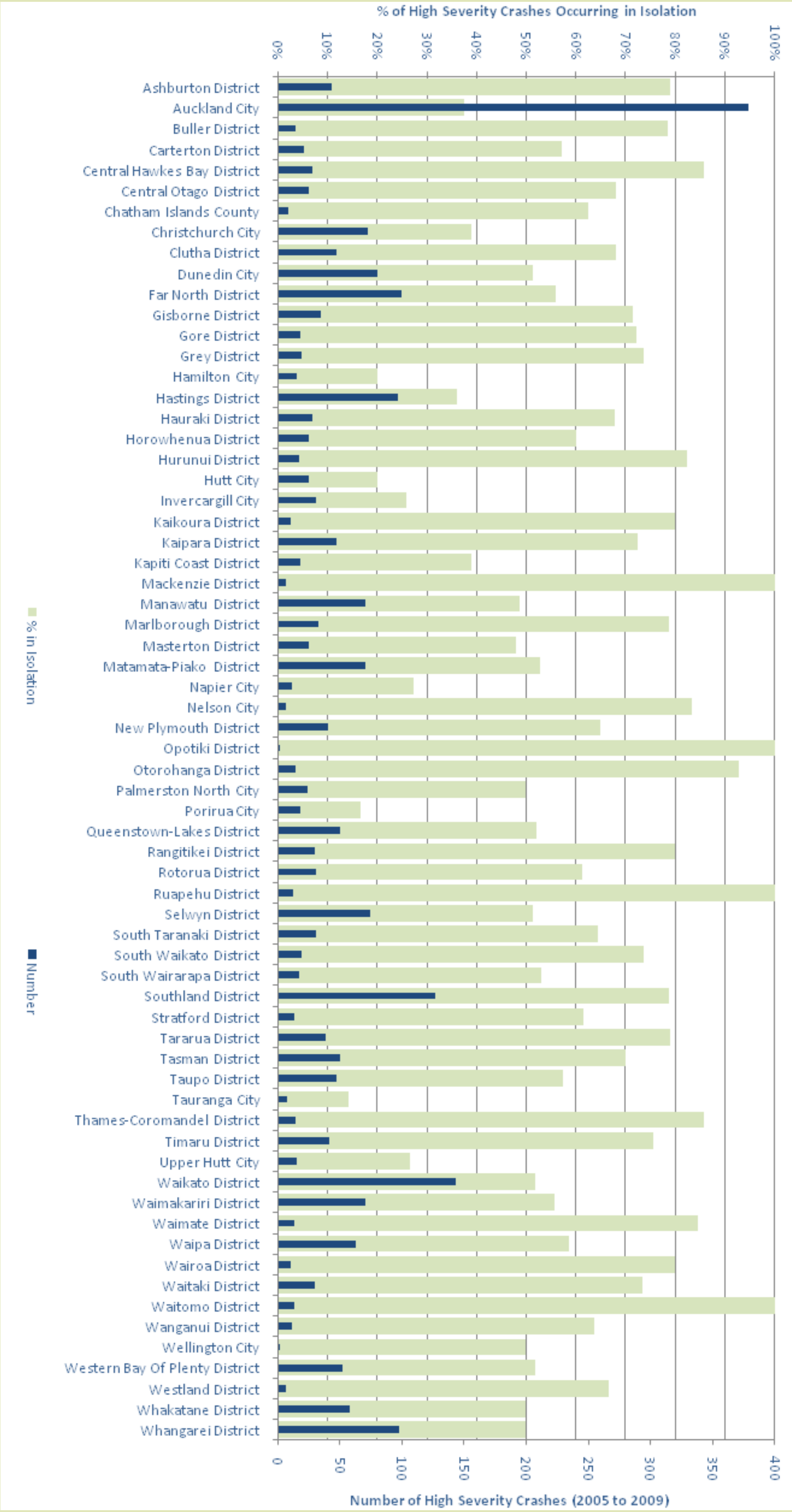
Fatal and serious injury crashes impose significant costs in terms of grief and suffering, as well as economic costs. It is for this reason that Safer Journeys and its Safe System approach focus on these high-severity crash types.

However, these high-severity crashes are typically highly dispersed. Nationwide, approximately 56% of fatal and serious crashes on local authority rural roads have occurred at locations where no other injury crash has been recorded in the past five years. That said, the proportions vary from TA to TA as does the actual number (see figure 3-2). Because of this there will be an increasing move to corridor or route treatments rather than focusing solely on crash clusters, thereby ensuring road users are provided with a consistent level of safety, appropriate to the route on which they are travelling.

If significant gains in road safety are to be made, priority should be given to addressing these routes and locations where high-severity crashes occur. This is the intention of the guide.

7 State highways and local roads combined – and with speed limits of 80km/h or more. Excludes motorways. Note that even though excluded from the overall data analysis in section 3 (because types of crashes occurring on motorways would skew results), motorways can still be included when defining a high-risk rural road.

FIGURE 3-2 The number of high-severity crashes (2005 to 2009 inclusive) by TA and the proportion occurring in isolation, ie no other reported injury crash with 250m radius



3.2 Comparing state highway and local road networks

As illustrated in figure 3-3, state highways comprise only 12% of the nation's road network. However, they account for over half of all rural road fatal and serious injury crashes. Figure 3-4 shows that the crash density, and especially the density of fatalities (the numbers per unit of road length), is proportionally higher on state highways than on local roads. The amount of travel on state highways represents approximately half of all vehicle kilometres travelled. Therefore, in relation to travel activity, fatal and serious crash rates are higher for rural state highways than for rural local roads.

FIGURE 3-3 All rural roads (excluding motorways): rural network length, travel and severe crashes

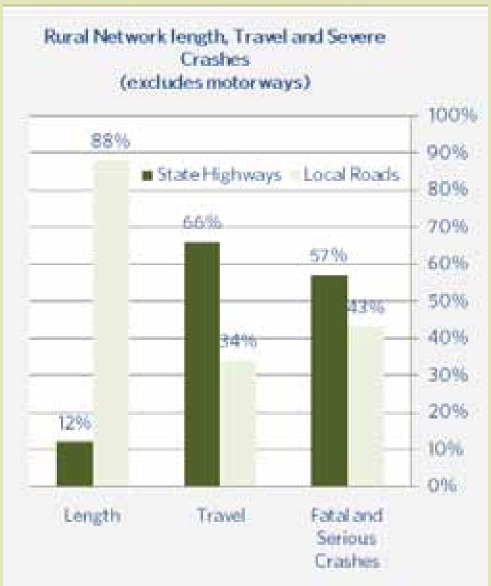
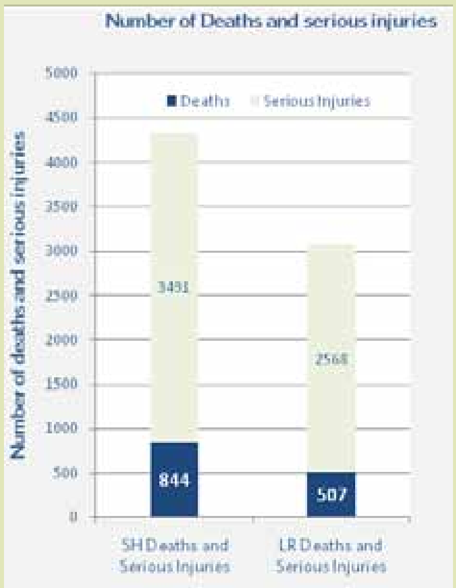


FIGURE 3-4 Number of deaths and serious injuries on rural state highways and local roads (2005–2009), excluding motorways



3.3 Key crash types

Although all crash types are used when identifying high-risk routes, the guide focuses on the three most common crash types for fatal and serious crashes on rural roads – 88% of all high severity crash types[8] occurring on New Zealand rural roads (excluding motorways) over the period 2005–2009 were: run-off road – lost control on curves[9] and lost control on straights, head-on, and at intersections which resulted in 90% of the total high severity casualties as outlined in table 3-1.

Analysis also shows that pedestrians and cyclists for 3% of fatal and serious crashes on rural roads, with the remaining 11% comprising a variety of other crash types.

TABLE 3-1 Key crash type percentage (all New Zealand rural roads excluding motorways) 2005–2009

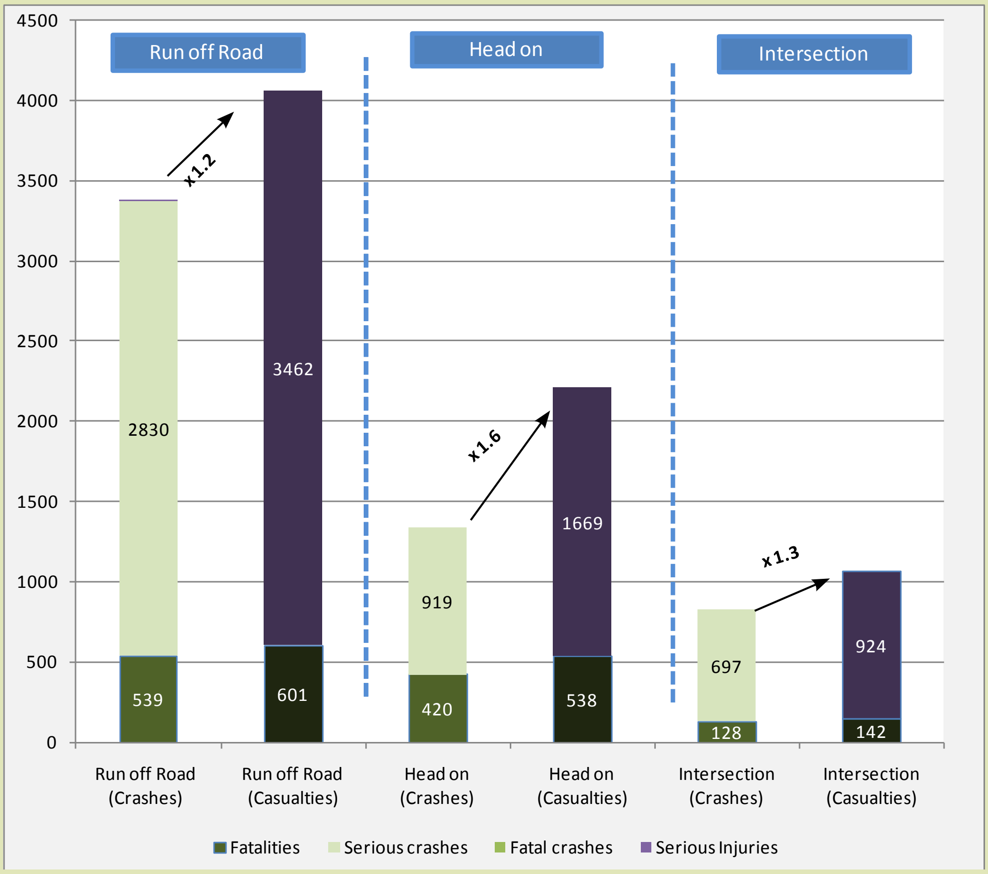
Key crash type	% of high severity crashes on New Zealand rural roads	% of high severity casualties from key crash types of all high severity casualties
Run-off road	54%	50%
Head-on	21%	27%
At intersections	13%	13%

8 Key crash types are defined in the NZTA's *Economic evaluation manual.*

9 For the purposes of this guide, it has been assumed that fatal and serious injuries due to loss of control on curves and straights equate to run-off-road on curves.

'Run-off road' crashes are the most common crash type in terms of both fatal and serious crashes and injuries (figure 3-5). However, when comparing fatalities across crash types, the number of fatalities in head-on crashes is of a similar magnitude to those in 'run-off road' crashes. In addition, there are more fatal and serious casualties for each head-on crash (1.6 times the number of fatal and serious crashes), due partly to more than one vehicle being involved. Furthermore, the ratio of severe injuries in intersection crashes is greater than in run-off road crashes.

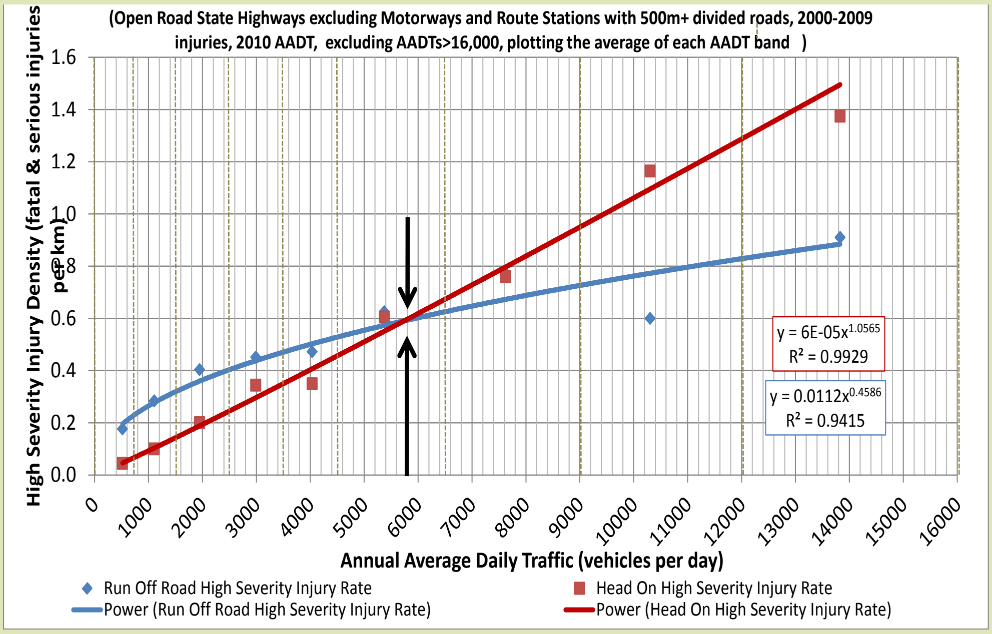
FIGURE 3-5 Key crash types – crashes and severity of crashes



For further information on the types of movement, codes are used for each key crash type (refer to figures 3-8, 3-9 and 3-10).

Figures 3-6 and 3-7 show the way the head-on severe injury density and rate vary with traffic volume. At above about 6000 vehicles per day, there are typically more people killed or seriously injured in head-on crashes than in run-off-road crashes. At low traffic volumes single vehicle crashes and casualties predominate because opposing traffic is infrequent. The risk of running off the road for each person reduces rapidly with increasing traffic. This is likely due to driver behaviour (such as excessive speed) being tamed by more traffic, but also to busier roads having higher safety standards. As roads get busier, head-on crashes and casualties increase in direct proportion to the amount of traffic, but the personal risk stays remarkably constant. Most head-on crashes result from loss of control so where a vehicle loses control and crosses the centreline, the outcome will only be a head-on crash if an opposing vehicle is present at the wrong time.

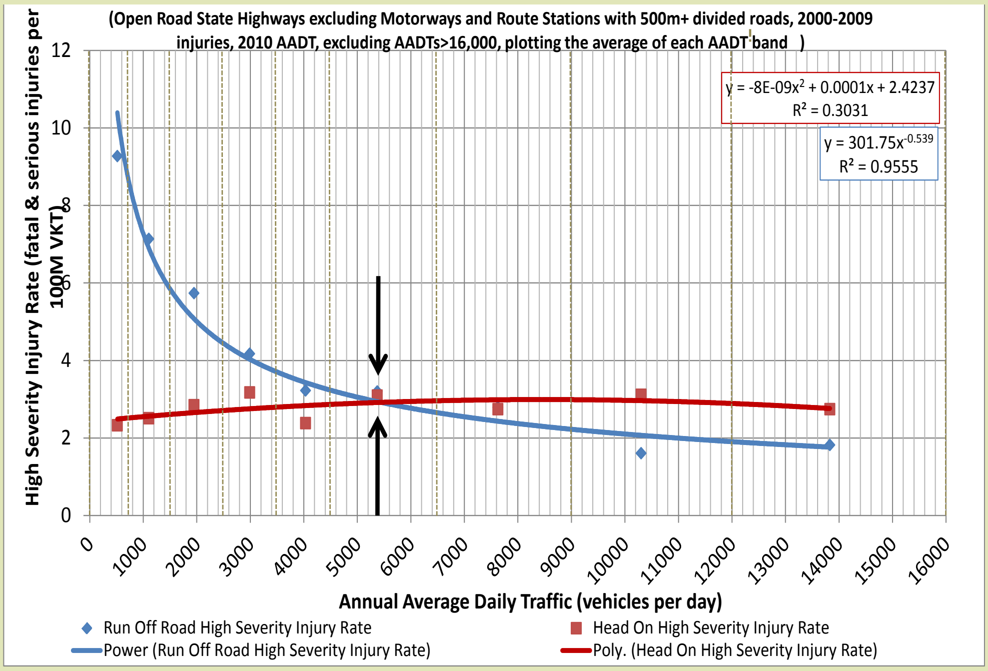
FIGURE 3-6 Run-off road and head-on injury density



Source: NZTA

Note: Figure 3-6 is based on casualties and is therefore a collective casualty risk.

FIGURE 3-7 Run-off road and head-on high-severity injury rates



Source: NZTA

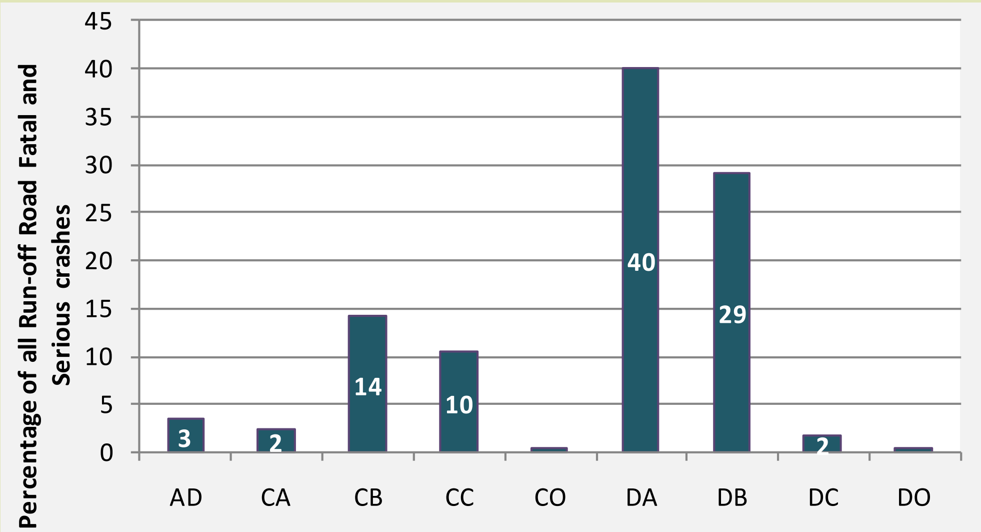
Note: Figure 3-7 is based on casualties and is therefore a personal casualty risk rate

Note: In the above graphs the data is the average of crashes and casualties on straights and bends. The casualty rate is less on straights and higher on bends so the graphs should not be used to predict crash rates. Crash prediction tools discussed elsewhere in this guide take all geometric variables into account when predicting run-off road and head-on crash risk.

3.3.1 Run-off road crashes

Loss of control (run-off road) crashes are the most common rural road crash type and account for 54% of fatal and serious crashes on all rural roads for the period 2005–2009. These types of crashes occur on both curves (69%) and straights (26%). The main type of movement is loss of control turning right, which represents 40% of all rural fatal and serious run-off road crashes (figure 3-9). The next most common movement types for run-off road crashes are lost control turning left (29%), lost control off-roadway to the left (14%) and lost control off-roadway to the right (10%), with the remainder equalling 7% of different crash movement types. Note that many vehicles initially leave the roadway to the left but while attempting to recover swerve across the road to the right.

FIGURE 3-8 Main movement types for rural run-off road crashes, fatal and serious–excluding motorways (2005–2009)



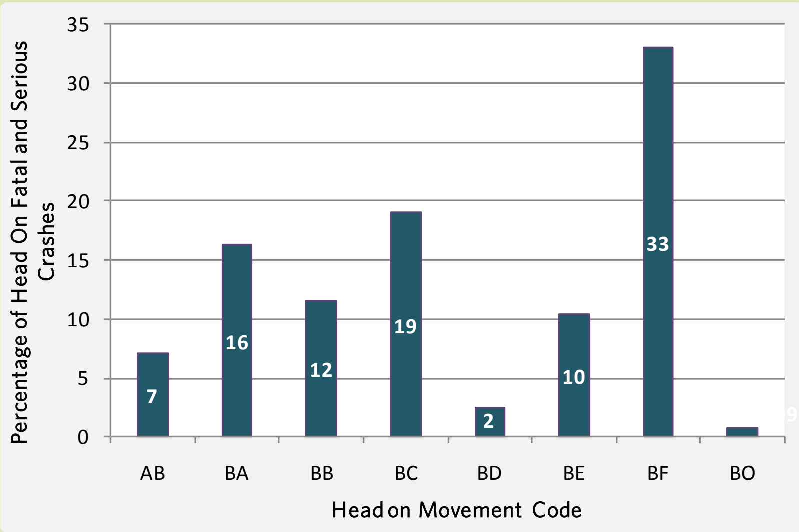
Over-taking and lane change	Lost control or off-road (straights)				Cornering			
AD	CA	CB	CC	CO	DA	DB	DC	DO
				Other				Other

KiwiRAP has specifically examined the level of road and shoulder width, road alignment, delineation on clear zones and barrier treatments on state highways, in order to rate the run-off road risks associated with those roads. In order to achieve a low risk rating (4 stars or greater), sufficient clear zones need to be provided, some form of barrier treatment, a good standard of alignment or an increase in shoulder width for recovery to address both the number and severity of run-off road crashes.

3.3.2 Head-on crashes

Head-on crashes represent the second highest fatal and serious crash type (approximately 21%) on all rural roads. Most fatal and serious head-on crashes happen on curves, consisting of loss of control (BF) 33%, swung wide (BC) 19% and cut corner (BB) 12%. Head-on crashes on straight roads accounted for 26%, consisting of failing to keep left (BA) 16% and lost control (BE) 10%. Head-on crashes while overtaking (AB) were only 7%.

FIGURE 3-9 Main movement types for rural head-on crashes, fatal and serious - excluding motorways (2005–2009)



Over-taking and lane change	Head-on						
AB	BA	BB	BC	BD	BE	BF	BO
							Other

In order to rate the safety on rural state highways, KiwiRAP[10] (discussed in section 4) takes into account the risk of head-on crashes, based largely on the level of median protection provided as well as other related factors, such as traffic volume, roadway alignment and width. Because most head-on crashes result from a vehicle that loses control, all the factors that contribute to losing control also influence a head-on crash. To achieve a low risk rating (4 stars or greater), higher-volume roads will typically need physically divided carriageways with a central median barrier, thus reducing the potential for head-on crashes. Varying types of median-separation measures and their application to all rural roads are discussed further in section 6 and appendix E.

The NZTA intends to initially target the highest-risk rural roads Some of those roads will be addressed by the roads of national significance (RoNS). Some New Zealand roads carry 15,000–20,000 vehicles per day but do not have median barriers. Installing median barriers[11] on all high-risk high-volume rural roads is estimated to save 8–10 lives per year and 102–119 injuries per year. [1]

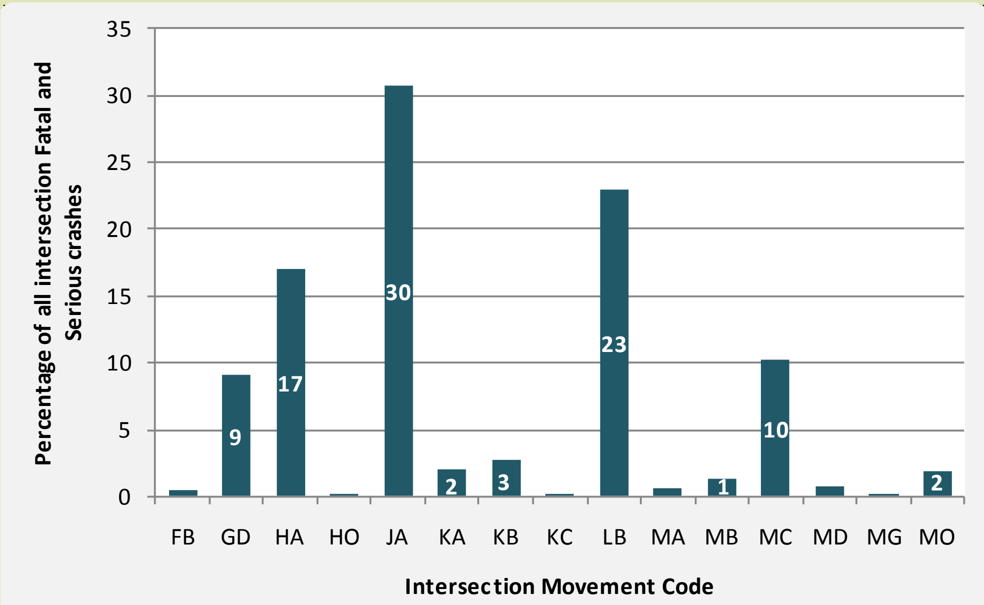
10 KiwiRAP is New Zealand's joint agency Road Assessment Programme.[3] The Ministry of Transport, the NZTA, Police, ACC and AA developed the programme to assess the risk of New Zealand roads and targeted it at decision makers and the wider public.

11 Other countries require median barriers on all high-speed routes that carry over 10,000–15,000 vehicles per day. [1] Sweden aims to install median barriers on all roads that carry more than 4000 vehicles per day.

3.3.3 Intersections

Intersection crashes are the third key crash type. The main type of intersection crash movement on rural roads involves traffic crossing from different roads (48%), with straight across (HA) comprising 17% and turning right from side road (JA) 31%. Vehicles turning right across traffic from the opposite direction (LB) make up 23%.

FIGURE 3-10 Main movement types for rural intersection type crashes, fatal and serious - excluding motorways (2005–2009)



Rear end	Turning vs same direction	Crossing (no turns)		Crossing (vehicle turning)	Merging		
FB	GD	HA	HO	JA	KA	KB	KC
CROSS TRAFFIC	NEAR CENTRE LINE	RIGHT ANGLE (70° TO 110°)	Other	RIGHT TURN RIGHT SIDE	LEFT TURN IN	RIGHT TURN IN	TWO TURNING
Right turn against	Manoeuvring						
LB	MA	MB	MC	MD	MG	MO	
MAKING TURN	PARKING OR LEAVING	"U" TURN	"U" TURN	DRIVEWAY MANOEUVRE	REVERSING ALONG ROAD	Other	

In order to achieve KiwiRAP's highest rating of 5 stars (ie the lowest safety risk), a route must have grade-separated intersections. Various forms of intersection countermeasures for high-risk rural routes are discussed in section 6 and appendix D.

For more information about intersection safety refer to the *High-risk intersection guide.*

3.3.4 Vulnerable road users

1 Pedestrians and cyclists

Due to the lower numbers of users present, crashes involving vulnerable road users (pedestrians and cyclists) are less prevalent on rural or open road networks, than on urban roads (less than 3% of crashes in rural areas). They are not one of the three main crash types. However, where pedestrians and cyclists are involved in open road crashes, the outcomes are typically severe, due to the often high speeds of traffic and the human body's limited tolerance of crash forces at speeds above 40km/h. As a result nearly two thirds of all New Zealand cyclist fatalities and one third of all pedestrian fatalities happen on rural roads. Clearly the personal risk to each cyclist and pedestrian is very high so where they are present their safety needs are important.

The inclusion of all fatal and serious crashes when identifying high-risk rural roads will help identify road sections that have high numbers of pedestrian and cyclist crashes.

2 Motorcyclists

Motorcyclists travel at high speeds with little protection and are at the highest personal risk of death and serious injury of any road users . On popular or high-risk routes any treatments proposed should recognise their vulnerability.

The inclusion of all fatal and serious crashes when identifying high-risk rural roads will help identify road sections that have a high-risk for motorcyclists. Refer to the *High-risk motorcycle guide* for further information.

Section 5.2.2 of this guide describes the main safety issues for motorcyclists on rural roads and introduces those countermeasures that are most relevant to their needs.

4 Identifying high-risk rural roads

The safety performance of a road is a function of:

- the likelihood of each user travelling on the road being involved in a crash
- the exposure or frequency, ie the number of vehicles using the route (traffic volume).

High-risk rural roads are essentially lengths of road with a higher than 'average' crash risk, and by implication are roads where targeted safety improvements are most likely to reduce trauma. High-risk rural roads are where the greatest reduction in severe casualties can be achieved, which is why they represent one of the highest Safe Roads and Roadsides priorities for investigation. However, there are also likely to be benefits from improving roads with moderate risks, or riskier spot locations (such as crash clusters/blackspots) on road lengths not formally classified as high-risk by this guide. Cost-effective solutions may be available for such sites and it is not the intention of this guide to stop blackspot studies and treatments, but rather to focus most attention on high-risk routes.

This section of the guide defines risk metrics and what constitutes a high-risk rural road and outlines how the various risk metrics that make up the definition of a high-risk rural road can be derived. Guidance has also been provided on how these metrics can be used to determine an appropriate treatment strategy, together with some examples of the process.

4.1 High-risk rural road definitions

A high-risk rural road is defined as:

- a rural road where the fatal and serious crash rate (personal risk) or crash density (collective risk) is classified as high or medium–high compared with other roads (section 4.4.1 and figures 4-1 and 4-2) and/or
- a high or medium–high collective risk and/or high or medium–high personal risk (as defined by KiwiRAP risk maps) (section 4.4.4) and/or
- a rural road that has engineering features that have the potential for fatal or serious injury crashes to occur as determined by the KiwiRAP star rating or road protection score (RPS), eg a road with 1 or 2 stars or an RPS greater than 10 (section 4) and/or
- an equivalent process such as the Road Infrastructure Safety Assessment (RISA) where personal risk is greater than 2.5 (section 4.4.3).

We have not defined a minimum road length. We have specified a minimum number of high severity crashes instead. The road sections must have crash histories of 3 or more fatal and serious crashes over a 5-year period or 5 or more fatal and serious crashes over a 10-year period. Desirably, lengths of road being considered should be corridors (maybe 10km or longer) or adjoining road sections with similar characteristics, traffic volumes, environment and road-use purpose. However shorter lengths can be considered. At the extremes a very short section of road with 3 or more high severity crashes will be a blackspot with a high crash density, whilst a very long section may have a low crash density (collective risk) albeit possibly a high crash rate (personal risk) and may only justify relatively low cost delineation improvements. In either case the process and countermeasures outlined in this guide are relevant.

With regard to predicted risk metrics (KiwiRAP star rating, RPS or RISA), we still do not define a minimum length; however, the likely crash numbers of 5 crashes in 10 years (ie at least 0.5 crashes per year) would need to be determined, taking into account the road length and traffic volume. An example of this is provided in appendix C.

4.2 Summary of process

The process of identifying high-risk rural roads in our networks should be completed at least every three years to provide information to support maintenance and renewal works included in the three-year National Land Transport Programme (NLTP). Table 4-1 shows the total process (from selection of the route to monitoring and evaluation) and table 4-2 summarises the processes we can use to determine high-risk rural roads. Detailed information on each of these is provided in section 4.5, with some description of treatment examples.

TABLE 4-1 General summary of process to determine, manage, implement and monitor high-risk rural roads

Select route	Crash data Risk maps (section 4.3)
Determine risk rating	CAS, RAMM, KiwiRAP, star rating, RPS, RISA (section 4.4)
Overall treatment philosophy	Section 4.5, figure 4-6
Understanding the issues	Section 5
Determine countermeasures	Section 6, and appendices D, E & F
Programme/project development/funding	Section 7
Monitoring and evaluation	Section 7

TABLE 4-2 Detailed summary of process to identify high-risk rural roads

Note that we only need to use one of these processes to determine whether or not we have a high-risk rural road. However, different processes may give different results, and if possible it is best to use several processes to determine a better understanding of the issues.

Using CAS Corridor or network-based analysis and screening	**Using RAMM** more appropriate than CAS for network wide screening	**Using RISA** (more appropriate where certain corridor assessment have already been completed	**Using KiwiRAP Risk Maps** calculated for longer lengths of highway (>5km), typically between town centres	**Using KiwiRAP Star Rating Risk Maps** calculated for longer lengths of highway (>5km)	**Using KAT (Star Rating and Road Protection Score)** more appropriate for shorter corridor investigations (>= 100m)
Select and plot high-severity crashes within a network or route to determine routes for further investigation	Use traffic crash data in RAMM to create an annual report from CAS which is linked to the RAMM road I.d (See appendix A)	Select studied routes within network	Select route/s from the published KiwiRAP maps for both collective and personal risk [Risk Metric] within your network	Select route/s from the published KiwiRAP maps for star ratings [Risk Metric] within your network	Select Network Maintenance Areas (NMA) or routes within NMA
Determine collective and personal risk **[Risk Metric]** for each of the routes (section 4.3.3)	Determine Collective and Personal Risk **[Risk Metric]** for each of the routes (section 4.3.3)	Filter out urban sites, short lengths of road, and corridors programmed for other infrastructure works	Determine the risk level of collective and personal risk **[Risk Metric]** maps (i.e high, medium-high, medium, low-medium and low)	Determine the risk level of the star rating **[Risk Metric]**	Filter out urban sites, short lengths of road, and corridors programmed for other infrastructure works
Determine whether there is a high-risk rural road* compared to other rural roads(section 4.4.1 using figures 4-1 and 4-2)	Determine whether there is a high risk rural road* compared to other rural roads.)section 4.4.1 using figures 4-1 and 4-2)	Filter out routes RISA value >2.5 for personal risk **[Risk Metric]** to determine whether they are a high risk rural road*	Determine whether there is a high risk rural road* using definitions (section 4.4.4)	Determine whether there is a high risk rural road* using definitions i.e star rating <3 (section 4.4.5)	Filter out routes with Star rating <3 or RPS >10 **[Risk Metric]** to determine whether they are a high risk rural road*

Use Treatment Philosophy Strategy (figure 4-6) to determine appropriate scale of treatments for the route

*For the collective and personal risk definitions, a minimum number of fatal and serious crashes will be needed, ie 3 or more fatal and serious crashes over a 5-year period and 5 or more fatal and serious crashes over a 10-year period. Similarly a section of road identified through the predicted risk metrics (ie RPS, star rating and RISA) must correlate with the equivalent of generating 3 high-severity crashes over 5 years (or 1.4 per year) or 5 high-severity over 10 years (2.8 per year) using figures C-1 and C-2 in appendix C.

4.3 Step 1: Process to calculate risk metrics

4.3.1 Risk metrics

Risk metrics are a set of measures to help determine crash risk. Generally, this can be defined in two different ways:

1 **Actual crash risk**: Actual crash risk is based on crashes reported in recent years and is, in theory, the primary measure of performance. It is most reliable where crashes are frequent, which happens on the busier roads where traffic volumes are also more reliable. However, on quieter roads, the crash density of fatal and serious crashes becomes too low to provide a reliable picture. KiwiRAP has already published some actual crash risk metrics (section 4.4.4). These are:

- collective risk maps
- personal risk maps.

2 **Predicted crash risk**: Predictive risk scores are most useful for roads with fewer crashes and lower traffic volumes, where the random nature of crashes can be misleading when dealing with small crash numbers. Because Safer Journeys and the Safe System approach focus on the less common fatal and serious crashes, predictive risk scores are important to ensure we don't implement measures that simply chase random crashes around the network. Metrics for predicting risk have also been developed for both state highways (KiwiRAP) and local roads (RISA programme). These are:

- KiwiRAP road protection score (RPS) (section 4.4.5)
- KiwiRAP star rating (published maps – section 4.4.5)
- Road Infrastructure Safety Assessment (RISA) (section 4.4.3).

Given the higher traffic volumes using the state highway network and the relatively high proportions of high-severity crashes, the initial release of KiwiRAP has focused on rural state highways. However, all RCAs are able to calculate collective and personal risk from their crash histories and traffic volumes.

The definitions for each of the risk metrics are as follows:

- **Collective risk** (also known as crash density) is a measure of the number of high-severity (fatal and serious) crashes that have happened per kilometre of road per year. Additional information and calculations are provided in section 4.3.3.
- **Personal risk** (or crash rate) is a measure of the number of high-severity (fatal and serious) crashes that have happened per 100 million vehicle kilometres of travel on the road. Additional information and calculations are provided in section 4.3.3.
- **Road protection score** (RPS) (100m) is a predictive measure of the personal safety of a road based on the presence or absence of road infrastructure features that are associated with the three major crash types on the New Zealand rural road network, ie head-on, run-off road and intersection crashes (section 4.4.4).
- **Star rating** (5km) is a predictive measure of the personal safety of a longer length of road based on the 100m RPSs and typically averaged over 5km lengths (section 4.4.4).
- **Road Infrastructure Safety Assessment** (RISA) is a technical review that assesses a sample of an approved organisation's road network to identify possible areas for safety improvement. This assessment method is still being trialled. It is based on international research that relates infrastructure features to crash rates, assesses the extent of these features on the road network, recommends high-level strategic actions to improve road safety on a network-wide basis and is used as an input to technical reviews (section 4.4.3).

By taking predictive rating scores for personal risk and converting them to personal risk using known relationships, it is possible to multiply them by traffic volumes to create predictive metrics that represent collective risk or crash density.

4.3.2 Selection of risk metrics for individual RCAs

To help RCAs identify high-risk rural roads, the following risk metrics can currently be used:

- for local roads:
  - collective and personal risk (formulas provided in section 4.3.3)
  - RISA scores (section 4.4.3)
  - note: at this stage, no KiwiRAP predicted crash risk metrics are available for local roads.

- for state highways:
  - collective and personal risk (formulas provided in section 4.3.3)
  - the KiwiRAP risk maps (section 4.4.4)
  - the RPSs and associated star ratings (section 4.4.5).

The followings sections (sections 4.3.3, 4.3.4, 4.3.5 and 4.4) provide guidance to RCAs on how to use both calculated crash risk parameters and KiwiRAP (risk maps, RPSs and star ratings) to identify high-risk rural roads and from these metrics how to determine the appropriate treatment philosophy.

4.3.3 Collective and personal risk metrics calculations

Having identified links of interest using CAS and/or RAMM, the personal and collective risk needs to be calculated. The following sections further discuss the definition and the calculation of collective and personal risk.

1 Collective risk

Of the two crash risks, collective risk or crash density is the easiest to quantify, and is simply the number of high-severity crashes divided by the length of road under consideration.

$$\text{Collective risk} = \frac{\text{(fatal crashes + serious crashes) / number of years of data}}{\text{Length of road section}}$$

There are two ways of collecting data to calculate collective risk: CAS or the RAMM databases.

Note that to be defined as a high-risk rural road there must be 3 or more high-severity crashes over a 5-year period or 5 or more high-severity crashes over a 10-year period.

Having calculated the collective risk, plot this value (figure 4-1) against the length of road we are considering to determine whether we have a high-risk rural road.

2 Personal risk

Personal crash risk (or crash rate) is in effect a measure of the likelihood of an individual road user being involved in a crash as they travel the road in question.

$$\text{Personal risk} = \frac{\text{Fatal crashes + serious crashes}}{\text{(length of road in km x number of years of data x 365 days x AADT) / }10^8}$$

Note: that to be defined as a high-risk rural road there must be a minimum of 3 high-severity crashes over a 5-year period or 5 or more high-severity crashes over a 10-year period.

Calculating the personal crash risk is more complicated because we need to establish the volume of traffic on the section under consideration (annual average daily traffic = AADT). Personal risk is typically calculated for a 5-year period, although in networks with lower traffic volumes and crash numbers a 10-year period may be more appropriate, provided there have not been substantial changes during this period.

Plot the calculated personal risk value for the length of road we are investigating (figure 4-2) to determine whether we have a high-risk rural road.

AADT data for the mid-year is preferred. If traffic data is not available for the mid-year, it is generally possible to use an appropriate growth factor to adjust flows from other years. As with collective risk, personal risk can be determined using RAMM, for example, provided the traffic volume data is reasonably reliable and does not vary much along the route being assessed.

4.3.4 Star rating and RPS risk metrics derivation

The star rating uses the RPS to determine a rating over a 5km length. These ratings were published in 2010 as part of KiwiRAP. To determine a rating for a particular length of road, reference can be made to the KiwiRAP Analysis Tool (KAT). Further detailed information is provided in section 4.4.5.

The RPS risk metrics can only be derived from KAT and are currently only available for the state highway network.

4.3.5 RISA calculation

Road Infrastructure Safety Assessment (RISA) is a process used by the NZTA's Technical Audit team to assess the state of the infrastructure associated with road safety on rural sealed roads in advance of the associated technical review of an RCA.

The objectives of the RISA system are:

- to determine the appropriateness of the road infrastructure to provide a 'safe' passage for users, accounting for traffic volumes
- to ensure that measures to eliminate or reduce the identified problems are considered fully by the RCA.

The methodology assesses only those road infrastructure features that are known, through New Zealand and overseas research, to be related to crash occurrence and/or severity. The features are grouped into categories, such as cross section including roadside hazards, alignment including delineation, surface including access provision, and intersections[12]. Note that the RISA process involves assessing the risk for each road section against a benchmark road that has been chosen for practicality of assessment. This benchmark road does not directly reflect current New Zealand standards and guidelines.

Data collected on the sample of road sections is applied to produce risk values for each road section. These risk values are combined, based on the spread of vehicle kilometres travelled (VKT) in the district surveyed to produce a personal risk (risk to individual road users unfactored), and collective risk (risk to all road users – factored with AADT), which when amalgamated produces a Network Risk Number (NRN).

This assessment process can be adapted to focus on higher-volume roads for an RCA and to provide personal risk scores for each. These scores indicate the 'relative' risks between road sections assessed and are comparable between RCAs.

To use figure 4-6 to determine whether we have a high-risk rural road, we would use a personal risk score of greater than 2.5.

4.4 Step 2: Process to determine a high-risk rural road using risk metrics

The six different processes outlined in table 4-1 can be used to calculate risk metrics to determine a high-risk rural road:

1. Crash data (section 4.4.1)
2. RAMM data (section 4.4.2)
3. RISA (section 4.4.3)
4. Published KiwiRAP collective and personal risk maps (section 4.4.4)
5. Published KiwiRAP star rating maps (section 4.4.5)
6. Road protection scores (RPSs) (section 4.4.5).

Each of these processes are described in the following sections (4.4.1 to 4.4.5).

4.4.1 Using crash data

We can use crash data to determine the crash density (collective risk) and crash rate (personal risk) comparison on all rural roads. Using CAS, map the crashes on our identified section of road and then use the measurement tool to obtain the length of the road section. This approach works well when looking at predefined links, but is cumbersome when seeking to screen a network. RAMM data (section 4.4.2) is better suited to network screening.

Once we have collected fatal and serious crash data and used the calculations in section 4.3.3 we can determine what our collective and personal risk scores are. These risk scores can then be compared with a number of other rural roads' risk scores (figures 4-1 and 4-2) to determine the relative risk of our road section, ie does it rate as a low-risk or high-risk relative to others[13].

Bands of collective and personal risk have been defined for each risk level. Each band contains approximately 20% of the routes when ordered according to both collective high-severity crash risk (figure 4-1) and personal high-severity crash risk (figure 4-2).

12 The intersections are assessed against best practice and design guidelines. At this stage the research on the relationship between crash data and specific intersection infrastructure features is not very strong. Accordingly the intersection data is only an overview of possible safety issues.

13 Note that the risk comparison is based on the state highway rural network, as this network has relatively complete traffic volume coverage; however, the figures can be used for all roads.

The following colours adopted for KiwiRAP and similar programmes can be used for each risk description on figures 4-1 and 4-2. For both collective and personal crash risk, medium–high and high define the route as a high-risk rural road, subject to having at least 3 ore more fatal or serious crashes in 5 years or 5 or fatal or serious crashes more in 10 years.

Having determined the collective and personal crash risks, as outlined in section 4.3.3, we need to seek to identify what types of improvement strategy are likely to be worthwhile (section 6).

FIGURE 4-1 Collective high-severity crash risk (crash density)

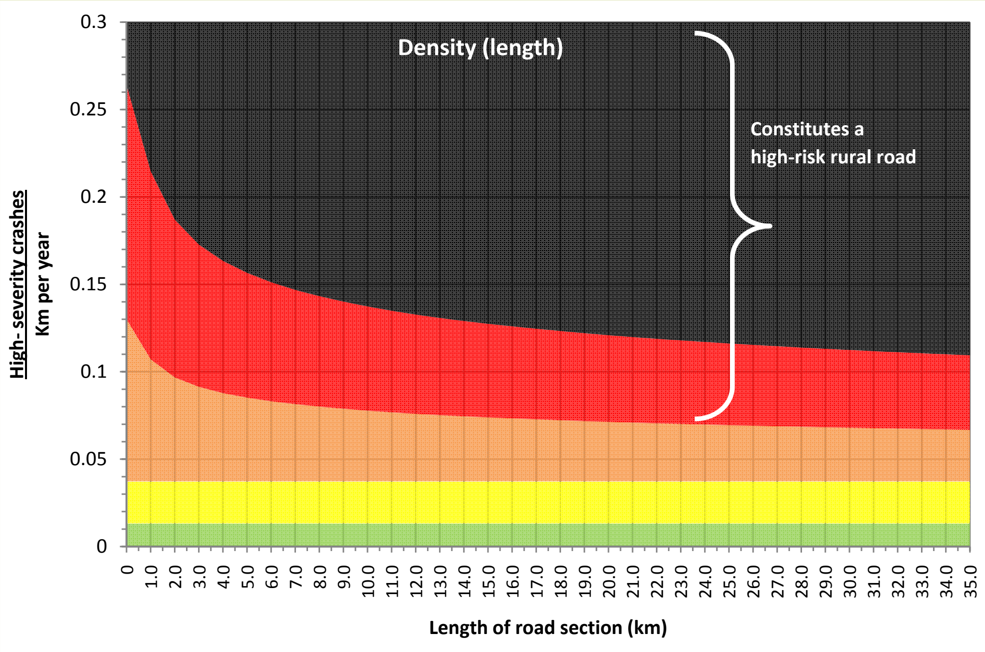
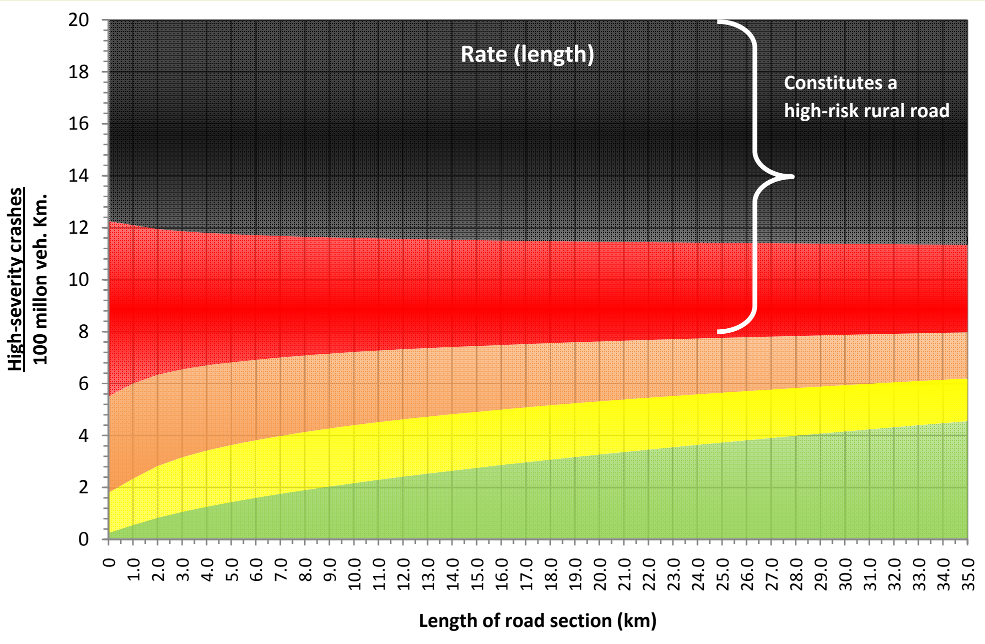
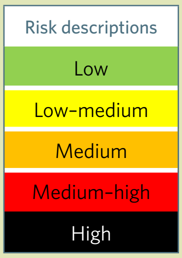


FIGURE 4-2 Personal high-severity crash risk (crash rate)





4.4.2 Using the Road Asset Maintenance Management database (RAMM)

RAMM is an alternative to CAS for calculating collective risk and is more appropriate for network-wide screening. Using the traffic crash data held in the databases operated by RCAs, an annual report from CAS can be created and exported. This is linked to the RAMM road_ID. Appendix A describes how to perform this calculation.

One of the key issues with this approach is the proliferation of relatively short links in many RAMM databases. Once plotted in RAMM Map or another GIS system, it is generally necessary to 'join up' sequential sections of road to define a publicly known route.

4.4.3 Road Infrastructure Safety Assessment (RISA)

RISA has been developed by the NZTA to ensure that it has factual information about the risks to road users as a result of the infrastructure on an RCA's road network.

The system involves visual assessment of infrastructure features that crash research has shown to result in crashes, on randomly selected road sections within an RCA network.

RISA outputs have been reviewed against actual road crashes and shown to be a very good indicator of crash risk potential.

RISA can generate both personal and collective risks for each road section assessed. To determine whether we have a high-risk rural road, we would use a personal risk score of >2.5.

4.4.4 Published KiwiRAP collective and personal crash risk maps

As part of developing KiwiRAP, a rating system to describe personal and collective risk in terms of a five-category ordinal scale was created using the descriptors in table 4-3.

TABLE 4-3 KiwiRAP risk map ratings

Risk descriptions	Collective risk (average annual fatal and serious injury crashes per/km)	Personal risk (average annual fatal and serious injury crashes per 100 million vehicle/km)
Low	≤0.039	<4
Low-medium	0.04≤+0.069	4 ≤4.9
Medium	0.07–0.10	5≤6.9
Medium-high	0.11≥0.189	7≤8.9
High	0.19+	9+

The 5-category scale helps practitioners appreciate where the collective and personal risks on the road they are considering fit within the national picture. A 5-category scale has also been developed for each of the KiwiRAP risk maps and star ratings (section 4.4.5, table 4-4). While each uses a five-category scale, they are not the same.

The KiwiRAP crash risk maps (figures 4-3 and 4-4) present both the personal and collective risks for 172 state highway routes, based on historic crash performance. These maps (www.kiwirap.org.nz/risk_maps.html generated in 2007 but released in January 2008) used fatal and serious crash data for the period 2002–2006, and it is expected that the maps will be updated in 2011/2012.

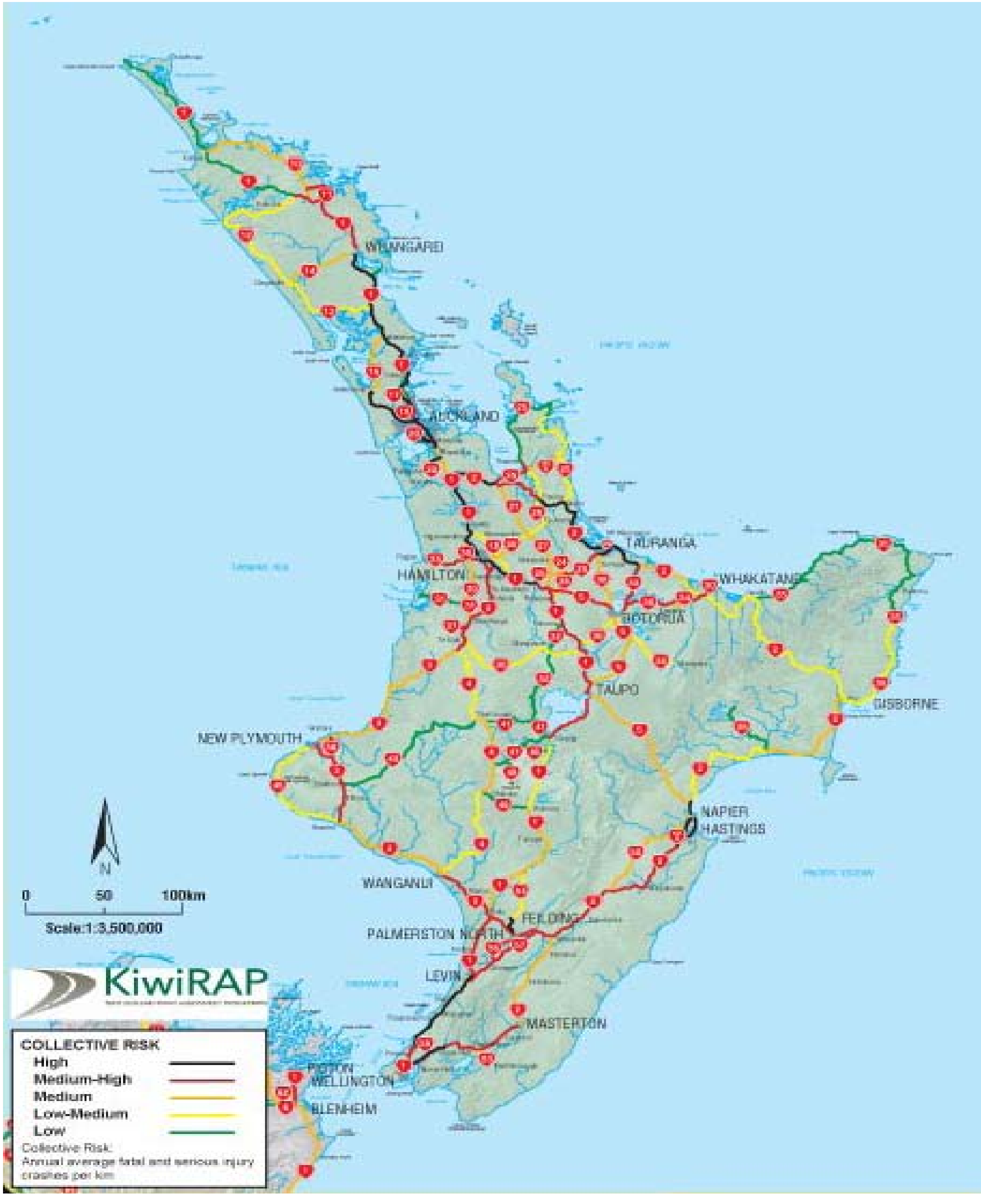
The state highway network has been divided into five bands, each containing approximately 20% of the routes (eg 20% of the routes are rated 'high', 20% 'medium-high'). However, the segment length used in the KiwiRAP risk maps averages some 60km. This is because the maps were initially aimed at informing the general public about travel risk and hence the links were selected primarily between major town centres or intersections of state highways. For statistical reliability purposes, each link was designed to have a minimum number of fatal and serious crashes, typically 30.

The way in which these state highway links have been selected has two effects:

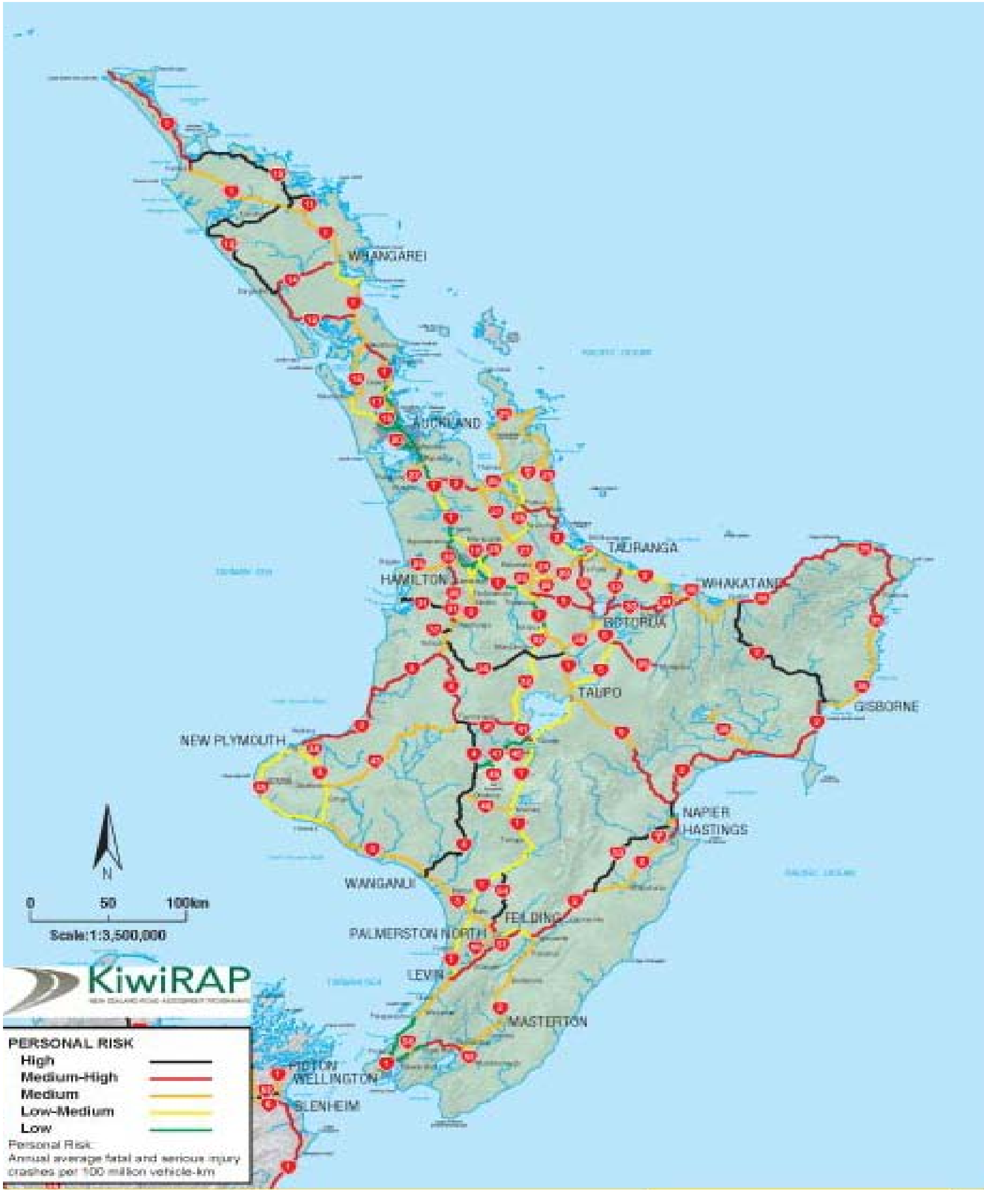
1. Many of the high collective risk links are shorter higher-volume sections typically located in the North Island.
2. The higher personal risk lengths tend to be longer lengths with lower traffic volumes and are typically in the South Island.

The result of these biases is that only 22% (2372km) of the rural state highway network has been mapped as 'high' or 'medium–high' in terms of collective risk, while 46% (4962km) has been mapped as 'high' or 'medium–high' in terms of personal risk. Within any particular link, there will be sections, sub-routes or corridors that may have higher risk ratings than the link itself and these sub-sections may be high-risk rural roads (sections) in their own right. Similarly, there will be lengths with lower risk ratings. That said, the KiwiRAP risk maps do provide a starting point for investigating high-risk rural routes as shown in examples in appendix G. Risk ratings of shorter state highway lengths can be determined by using the methodology presented in section 4.4.1.

FIGURE 4-3 KiwiRAP North Island risk maps
(collective risk – this page, personal risk – adjacent page



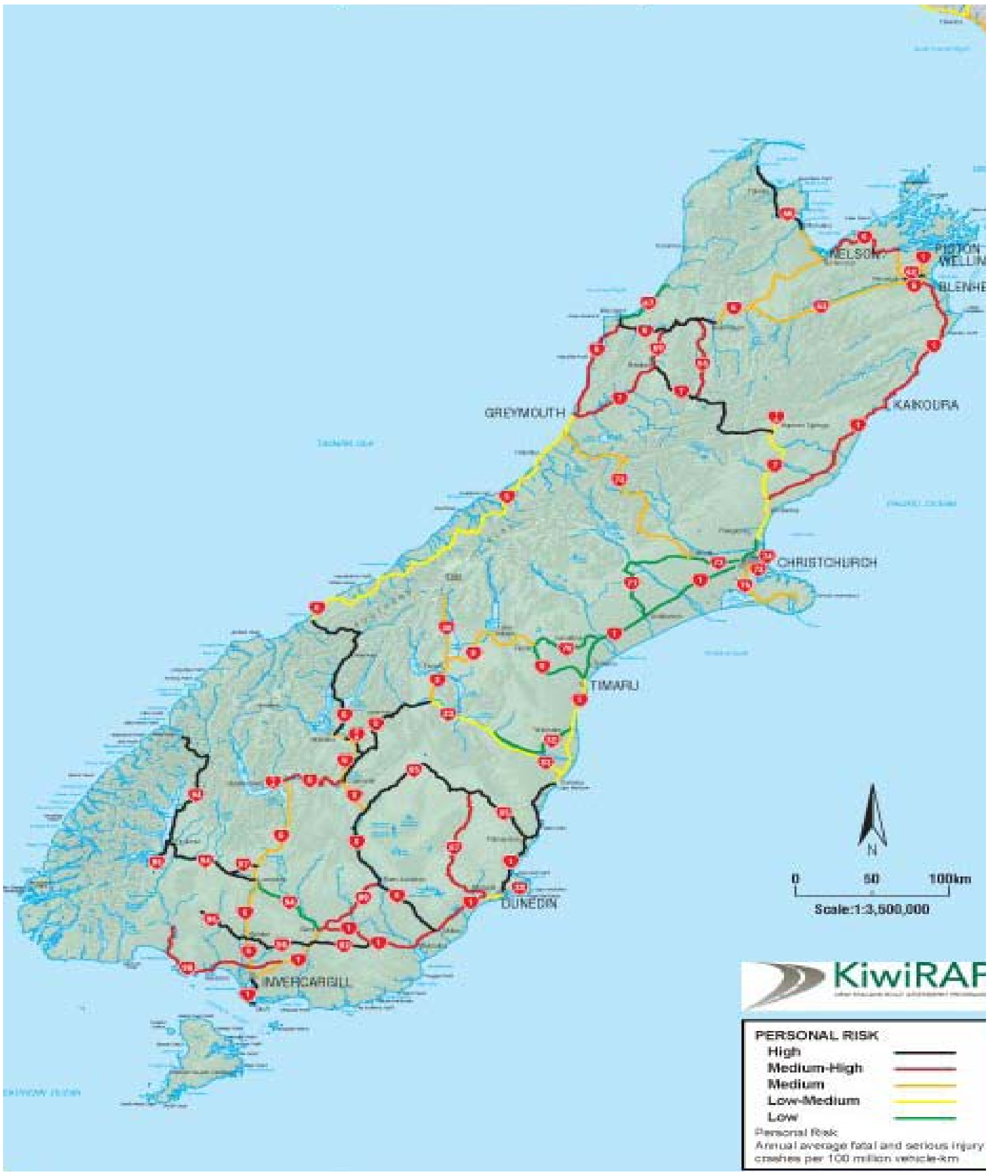
(Note: The user should refer to the website for the most up-to-date and regional versions)



(Note: The user should refer to the website for the most up-to-date and regional versions)

FIGURE 4-4 KiwiRAP South Island risk maps
(collective risk – this page, personal risk – adjacent page)

(Note: The user should refer to the website for the most up-to-date and regional versions)



(Note: The user should refer to the website for the most up-to-date and regional versions)

4.4.5 Published KiwiRAP star ratings and RPS (state highways)

The second KiwiRAP protocol – the KiwiRAP RPSs and associated star ratings – also provides a means of identifying high-risk rural roads through predicted crash risk. The KiwiRAP RPS and associated star rating measure the safety of a road based on the presence or absence of road infrastructure features that are associated with the three major crash types on the New Zealand rural road network: head-on, run-off-road and intersection crashes.

TABLE 4-4 KiwiRAP star rating and road protection score

Risk descriptions	Star rating (5km)	Road protection score (100m)
Low	5	<1.05
Low-medium	4	1.05–4.5
Medium	3	4.5–10
Medium-high	2	10–25
High	1	>25

The strong relationship between the RPS and crash rate (injury crashes per 100 million vehicle kilometres of travel) means that KiwiRAP RPSs or star ratings can be used as a surrogate but more proactive measure of personal crash risk. Appendix C describes the relationship between KiwiRAP star ratings and personal risk.

More importantly the KiwiRAP RPSs have been calculated for every 100m section of rural state highway. These have then been averaged over 5km lengths to produce the star ratings (see figure 4-5).

A more detailed discussion of the KiwiRAP RPS process and the resulting star rating maps can be found at www.kiwirap.org.nz/pdf/KIWIRAP%202010%20book%20low%20res.pdf.

Due to the enormous volume of data underlying the KiwiRAP RPSs and star ratings, the NZTA has created the KiwiRAP Analysis Tool (KAT), which allows practitioners to identify and investigate sections of the state highway network that meet particular criteria. For example, KAT would enable a user to find sections of highway with an RPS of 10 or more (these are 2 star sections) and carrying more than 5000 vehicles per day.

Because the KiwiRAP star ratings and risk protection scores can be converted to predictions of personal risk, it is a simple matter to then multiply the predicted personal risk by the traffic volume to predict the collective risk or crash density. However it is important to recognise the limitations of this process. The RPS scores are based primarily on the engineering features of the road sections, although other factors like skid resistance and climatic conditions are not included.

FIGURE 4-5 KiwiRAP star ratings

(Note: The user should refer to the website for the most up-to-date and regional versions)

(Note: The user should refer to the website for the most up-to-date and regional versions)

4.5 Treatment of high-risk rural roads

This section provides guidance on how to use the above risk metrics to determine an appropriate treatment strategy, together with some examples of the process.

4.5.1 Process

Using the process explained in sections 4.2, 4.3 and 4.4 we have now determined the level of risk is. Using these calculated risk levels for collective and personal risk, we can use the 'treatment philosophy strategy' (figure 4-6) to determine the likely appropriate level of treatment for our route or site. A detailed explanation is provided in section 4.5.2.

4.5.2 Safety Improvement Strategy

Figure 4.6 provides a schematic of the general treatment philosophy strategy that has been developed to guide the selection and implementation of various improvement measures based on the various metrics that define the risk of a particular route under consideration. These are:

- actual crash data such as collective risk (shown on the top horizontal x-axis), and personal risk (shown on the left-hand vertical y-axis)
- predictive crash scores (RPS, star rating or RISA) (shown on the right-hand vertical y-axis). In addition, a correlation chart (appendix C) has been provided to convert KiwiRAP personal predictive risk scores to crash rates, if needed. Predictive personal crash rates can be converted to predictive collective risk simply by multiplying by traffic volume.

To use the chart we need to have at least two metrics, one on the x-axis (ie collective risk or traffic volume) and one on the y-axis (ie personal risk, RISA, RPS or star rating) to determine an appropriate treatment strategy.

The upper right portion circle quadrant of figure 4-6 shows those routes with both high personal risk and high collective risk. A high personal risk score provides scope for potentially large reductions in personal risk. When high personal risk occurs on higher-volume routes, the result is a high crash density. There is considerable scope to reduce personal risk, and there are likely to be sufficient crash reduction benefits to justify larger infrastructure improvements.

At the other extreme, in the lower left quadrant, both the personal crash risk and the resulting crash density (typically at lower traffic volumes) are low; there is in effect no serious safety problem. That said there may still be scope for treating crash clusters or shorter sections of the route for which crash data or other tools such as KiwiRAP predict higher levels of risk.

The lower right quadrant comprises routes with relatively low personal risk but typically higher traffic volumes. In these situations safety improvements are less likely to significantly reduce personal risk but the high volumes can generate significant benefits, although probably not sufficient to see a complete transformation of the road environment. In these situations, incremental improvements (such as hazard management, side barriers, median treatments or other theme-based interventions along the route) are likely to be the most appropriate approach.

The upper left quadrant is characterised by high levels of personal risk but lower traffic volumes result in low crash density. On these roads, the potential crash reduction benefits will be limited, and strategies focused around ensuring the highest levels of signage, delineation and road surface maintenance and management will be most common. Specific attention should be paid to speed management recognising that appropriate speeds will reduce both the likelihood and severity of crash outcomes. Using various methods (as outlined in table 4-2) we have worked through a number of examples for different state highways and local roads. These are included in appendix G.

When considering the crash pattern on routes, there is almost a continuum of safety performance that needs to be investigated.

FIGURE 4-6 Treatment philosophy

1 What type of safety problem do we have?

Figure 4-6 provides guidance on the overall form of the corridor improvement strategy but not necessarily the specific measures that may be most appropriate. The first step in such an investigation is to determine what type of safety problem we have, whether the current crash patterns have either geographical or thematic commonality, whether they are clustered (black or grey spots) or whether there is a common theme, eg lost control on curve in dark. Although there may not be specific black or grey spots, subsections of the route may appear to have more crashes than other sections.

Guidance for understanding the safety issues is given in section 5. Further analysis and treatments of crash clusters (or blackspots) can also be found in the *New Zealand guide to the treatment of crash locations.*

2 Interim safety treatments

It is recognised that where Safe System Transformation Works are identified as the most appropriate treatment strategy it is likely to involve a long-term period of incubation and implementation given the higher cost of infrastructure-type treatments. Therefore consideration should be given to providing interim safety treatments where they could still be cost effective, ie the treatment should not create difficulty or increase costs significantly when programming for larger infrastructure works in the future.

4.6 Performance and safety improvement potential of high-risk rural roads

The safety improvement potential can arise through one of two mechanisms:

- Route A carries 1000 vehicles per day over 10km and has had three high-severity crashes in the past five years equating to 16 high-severity crashes per 100 million vehicle kilometres of travel. This equates to a high personal crash rate (typically >12 high-severity crashes per 100 million vehicle kilometres of travel) for this length of road. As a result there is considerable potential for highway improvements to reduce the personal risk. This could be in the order of a 62% reduction in the personal crash risk if it could be lowered to mean personal risk rate of 6.
  Note: Extreme caution would need to be exercised in calculating the crash rate based on such a low number of reported crashes that are high-severity, and a 10-year period should probably be considered, or alternatively crash prediction models used.
- Route B is also 10km and carries 9000 vehicles per day and has had 12 high-severity crashes, equating to a medium–high severity crash rate of 7.3 fatal and serious crashes per 100 million vehicle kilometres of travel. Undertaking works that reduce the crash rate to a slightly lower rate of 6 high-severity crashes per 100 million vehicle kilometres of travel would result in an 18% reduction in personal crash risk.

Table 4-5 shows the expected benefits of improvements to these routes.

TABLE 4-5 Example of crash reductions

Route	Length	AADT[1]	vkt[2]/5 years (100 million)	Situation	Personal risk high-severity crashes/100 million vkt[2]	Collective risk high-severity crashes/km/yr	High-severity crashes / 5 years
A	10km	1000	0.1825	Before	16 (high)	0.060 (med)	3.0
				After	6 (med)	0.026 (low–med)	1.1
				Reduction	62%	0.014	1.9
B	10km	9000	1.6425	Before	7.3 (med - high)	0.240 (high)	12.0
				After	6 (med)	0.198 (high)	9.9
				Reduction	18%	0.042	2.1

1 Annual average daily traffic 2 Vehicle kilometres of travel

So while treatments to Route A may significantly reduce personal risk, a more moderate reduction in the crash rate on the higher-volume Route B could give a better safety outcome, ie a greater reduction in the number of people killed or seriously injured. However, this will not always be the case and the purpose of this example is to demonstrate the need to assess both collective risk and personal risk.

Route A only justifies low-cost safety management type treatments while Route B probably justifies at least Safer Corridor type treatments to bring collective risk to below high.

Combining both personal and collective risk metrics guides the analyst toward the types of treatment philosophy (figure 4-6) that may best suit the length of highway under consideration; there is effectively a matrix of solutions. Further detailed information on route treatments is discussed in section 4.5.

5 Understanding the issues

As discussed in section 4 of this guide, we have determined where our high-risk rural roads are through a set of processes. This process worked predominantly on the basis of using high-severity crashes (ie fatal and serious injuries) to determine our highest-risk routes or sites. Although using high-severity data is the underlying factor in determining these routes, it is important to provide further analysis on all crash data and other factors to better determine the safety problem and the most appropriate countermeasures for our treatment strategy.

5.1 Analysing the data

Crash analysis is essential before choosing countermeasures. Using all the crash data rather than just the high-severity crashes provides a larger sample size to enable us to identify the risk issues and make more informed decisions on what type of countermeasures may be appropriate for any given route/site.

Risk analysis uses the crash prediction tools that identify the factors that may be contributing to crash risk. This may help supplement any detailed crash analysis

In these investigations the road safety practitioner should look to understand:

- crash patterns for both:
  - high-severity crashes, ie those resulting in death or serious injury, as they may differ from lower-severity crashes
  - all crashes (the inclusion of minor and non-injury crashes will better highlight spatial, temporal and crash movement commonalities or factor patterns)
- the spatial location of crashes – whether they are clustered or distributed
- key risk factors such as lengths, proximity to road users and severity of hazardous roadsides
- consistency of expectation and provision of road features and roadside infrastructure.

In addition to this section it is recommended that the NZTA's *New Zealand guide to the treatment of crash locations* and *Austroads: Part 8 Treatment of crash locations* are referenced for additional details on diagnosing crash problems.

Other data that could help develop treatments would include changes to development/residential/commercial growth in the area, traffic volumes, and key stakeholder and community concerns.

Where pedestrians, cyclists and equestrians are present, the NZTA's draft non-motorised user review procedures should be consulted to assist in defining the issues.

5.2 Detailed crash analysis

To help understand the safety problems, a detailed analysis of the crash data is required. Although the CAS plain english and coded reports will assist, it is strongly recommended that the original traffic crash reports are analysed and reviewed, as these provide information not available in the summary reports.

The **general factors** that need to be understood are crash movement types, midblock versus intersections, direction of travel, temporal factors (day of week, time of day, month of year) and day or night.

The specific **roads and roadside factors** that need to be understood are straights versus curves, wet or dry road conditions (refer to section 5.2.1), objects struck, and other road factors (such as surface material, sight distance, etc)

Issues to consider in addressing these include consistency and readability of the alignment, signage and delineation, carriageway width, skid resistance, median treatments, and hazard removal, protection or mitigation.

The specific **speed factors** that will need to be understood include drivers travelling too fast for the conditions versus speeding (ie exceeding the posted speed limit) and time of day and traffic conditions for speed-related crashes.

The specific **road user factors** that need to be taken into consideration include their age, sex, licence status, and if alcohol, speed, fatigue or inattention was involved etc.

The specific **vehicle factors** that need to be understood are the age, type and condition of the vehicle.

The specific **vulnerable road user** factors that need to be understood are what levels of pedestrian, cycle and motorcycle activity are present, and the age and other characteristics of other road users (see section 5.2.2).

It is important to understand the issues as the treatment may live in more than one part of the Safe System. For instance, road user factors such as inattention and fatigue can be addressed through road interventions such as rumble strips and barriers and in the future speed may be managed by vehicle advancements such as Intelligent Speed Assist (ISA) etc.

5.2.1 Environmental factors

Wet and dark crashes

Two key crash types are worthy of additional consideration: wet weather crashes and those occurring in dark conditions. This information is shown in appendix B. These tables group both the local road and state highway networks according to the nine climatic zones shown in figure 5-1. A list of the allocations is contained in appendix B.

While the relative proportions of crashes occurring in different conditions will vary according to travel volumes and patterns and operating speeds, comparing the relative proportions can provide valuable insight into potential problems and issues. Two examples of sites that have an abnormally high instance of either wet or dark crashes are described below:

Example (a): A section of SH29 on the Kaimai ranges linking the Bay of Plenty and Waikato regions has 16 bend lost control/head-on high-severity crashes, of which 10 (63%) occurred in the wet. SH29 is in the northern New Zealand climate zone where we would expect about 37% of bend lost control/head-on crashes to have occurred in the wet (appendix B).

Further investigation into the crash data on SH29 shows that 6 of the 7 bend lost control/head-on crashes in 2008 and 2009 occurred in the wet. A review of the SCRIM[14] values for this highway (in the past two years) indicates that they have been at or below the level required (in accordance with NZTA T10 standard) for investigation.

Example (b): A section of SH3 south of Whanganui shows 30 high-severity crashes over a 10-year period (2000–2009), of which 14 (47%) occurred in dark conditions. Compare this with the percentage of high-severity crashes on open state highways in dark conditions for all crash types for this south-west North Island area – 36% (appendix B). This route shows 30% more dark crashes than would be expected.

Further analysis could be completed on the types of crashes and then what associated treatments could help reduce those crashes, ie if there is a high percentage of loss of control crashes on bends in night-time conditions, delineation treatments (signs, makings, etc) along the route should be checked.

14 Sideway-force Coefficient Routine Investigation Machine.

FIGURE 5-1 New Zealand climatic zones

5.2.2 Vulnerable road users

When developing solutions, both crash data and road user information is needed to understand the level of use and road issues associated with motorcyclists, pedestrians and cyclists both along and across the road corridor.

If crash analysis or community and key stakeholder feedback has identified that a significant number of cyclists, motorcyclists or pedestrians use this route, then considering appropriate facilities for these types of road users is important when developing any treatment. In a few cases specific provision for them will be warranted. For the rest, the development of countermeasures for the main motor vehicle crash types will need to consider their needs. For instance, if a route has a high head-on crash rate and/or risk, then one of the most appropriate solutions may be to install a central median barrier. However, installing a median barrier will require the lanes to be shifted, reducing the available shoulder. The presence of pedestrians and cyclists may add to the case for widening the seal to maintain a shoulder width adequate for their needs.

1 Motorcyclists

Motorcyclists have well-defined main crash types, with a distinct pattern. The main motorcycle crash types that lead to fatal or serious injuries on rural roads excluding motorways are as follows:

- **Off-road or head-on on bends** (57%) are by far the most frequent crash type. Right-hand bends were twice as risky as left-hand bends. Only 22% of the bend crashes involved a head-on collision. Surface condition and slippery surface were frequently mentioned in crash reports.

  This suggests a focus on the outside of curves, including generous road shoulders, forgiving roadsides, and surfaces with good friction that are free of debris. Many motorcyclists find it difficult to change their line once committed to a bend so delineation needs to be consistent so that a curve is properly read from the approach. Curves that tighten unexpectedly are especially difficult for motorcyclists.

- **Intersection-type conflicts** (18%) mainly involve a driver who failed to yield to a motorcyclist usually because the motorcyclist was not seen in time. There is a subset of these where a motorcyclist was overtaking a vehicle slowing to turn right.

  Excessive visibility from the side road approaches to intersections can lead to drivers looking too soon and failing to notice approaching motorcyclists, so countermeasures that optimise the visibility triangle are beneficial – especially at crossroads and roundabouts. Right-turn bays help to reduce the overtaking problem.

2 Cyclists

About half of all rural fatal and serious cyclist injuries result from rear-end collisions or sideswipes by vehicles coming from behind the cyclist. So where significant cyclist activity is present, the most important countermeasure is to provide sufficient space in a road shoulder of consistent width, and to ensure the road shoulder provides an appropriately clean and smooth surface for cyclists so they will use it. While full design widths are desirable, even modest shoulders are beneficial. Where cyclist volumes are considerable, greater separation is desirable. Pinch points where the roadway narrows and cyclists need to move close to or into the traffic are a particular hazard. The extent of the narrowing should be reduced as much as possible or managed by measures such as active signs.

About one third of rural fatal and serious cyclist injuries result from intersection and driveway conflicts, with the severe injuries resulting from cyclists failing to yield to faster motor vehicles. These typically happen when turning right across traffic from behind and when entering from driveways and side roads.

Cyclists are also vulnerable when circulating around faster multi-lane roundabouts and when squeezed by heavy vehicles on the approaches when the rear of a heavy vehicle cuts in while turning left. For this reason cycle lanes and marked shoulders are not recommended for the approaches and circulating areas of most roundabouts. The safest option for rural roundabouts is to provide a separate cycle path.

3 Pedestrians

Fatal and serious pedestrian casualties are evenly split between those where a pedestrian was crossing a road and those where a pedestrian was walking along a road. There is a significant group where pedestrians were unnecessarily standing or even lying on the road.

Where pedestrians are known to cross the road in significant numbers, the basics of adequate visibility, minimising crossing distances, speed management and clear delineation between the roadway and the pedestrian spaces are most important.

For pedestrians walking along the road, having a place to walk outside the traffic lanes is important, as is street lighting for highways through small rural communities.

Further information on pedestrian facilities is in the NZTA's *Pedestrian and planning design guide,* while cyclist information can be sourced from the NZTA's website (www.nzta.govt.nz), and Austroroads guidelines [132]. Details on addressing motorcycle routes can be found in the NZTA's *High-risk motorcycle guide* (currently under development).

5.3 Unsealed roads

Unsealed roads, although not likely to be considered a high-risk rural road, are associated with a number of issues that the RCA needs to consider.

Crashes for unsealed roads in New Zealand are typically lost control on bends and head-on type movements, which account for 61% of all unsealed road crashes for 2006–2010.

As outlined in the ARRB Guide [120], the general issues encountered by drivers are generally:

- low levels of enforcement
- longer emergency response times
- traffic composition, which may include a higher percentage of heavy vehicles.

The main types of issues for roads and roadsides are:

- poor surface conditions
- poor geometric standards
- inconsistent road driving conditions
- collisions with native animals
- lack of delineation.

In addition, there is generally a lack of protection from roadside hazards on New Zealand rural unsealed roads.

Typical driver causes are poor handling, travelling too fast for the conditions and poor judgement. The ARRB Guide states that 'higher travelling speeds can be a result of the typical low traffic volumes'.

Road safety measures for unsealed roads tend to be within the safety maintenance and management quadrants of the treatment strategy diagram (figure 4-6) and are generally low cost.

For additional information on managing and strategies to improve safety, reference the ARRB Guide. [120]

6 Countermeasures

Under a Safe System, system designers create and operate a transport system where responsible road users are protected from death and serious injury. The countermeasures for high-risk rural roads identified in this section relate specifically to the Safe Roads and Roadsides and Safe Speeds cornerstones of the Safe System (section 2).

This section describes a number of Safe System treatments and incremental countermeasures that have been proven to reduce both the number and severity of crashes. A Safe System approach focuses on providing higher-level infrastructure measures or applying Safe Speed thresholds to achieve the Safer Journeys' vision of 'A safe road system increasingly free of death and serious injury'. However, larger-scale infrastructure projects may not be achievable in the short term, nor practicable/feasible for low-volume high-risk rural roads, particularly those with a high personal risk but low collective risk. In many situatoins lower cost treatments may be more suitable than providing a Safe System, as they can still result in significant savings in death and serious injuries.

6.1 Section layout

This section is divided into specific countermeasures. Each countermeasure includes the following:

Description	Describes the countermeasures
Application	How the countermeasures can be applied
Issues	What issues are associated with using the countermeasures
Crash reduction	The effectiveness of the countermeasure. Crash reduction percentages are sourced from a variety of references and therefore there are a range of values
Other benefits	What other benefits we get by using the countermeasures
Cost	Cost can be site specific (eg grade-separated interchange) or cost per kilometre (such as length of median barrier). Costs are sourced from a variety of references and therefore there are a range of values. These should be considered indicative only
Treatment life	Describes range of years as deterioration can be site specific. Treatment life is sourced from a variety of references and therefore there are a range of values
References and guidelines/guidance documents	Any sources of information used to describe or evaluate the countermeasure noted as a [ref.no] (section 8)

6.1.1 Crash types

The countermeasures in this guide have been selected because they are specific to reducing the three key rural road crash types. Other crashes will be addressed as a result of these countermeasures, and other site-specific, crash-specific or safety deficiency associated treatments can be sourced from various locations. Although, motorcyclist and cyclist crashes are not specifically addressed within this document; consideration has been given to how specific treatments may impact on these types of road users.

The Safe System Infrastructure countermeasures are referenced first and show the largest reduction in the three key crash types compared to other Safer Corridors and Safety Management countermeasures.

6.2 Treatment philosophy strategy

Table 6.1 shows the five key treatment philosophies for countermeasures for high-risk rural roads:

- Safe System Transformation Works
- Safer Corridors
- Safety Management
- Safety Maintenance
- Site-specific treatments

Detailed information is provided in sections 6.2.1–6.2.4

The treatment philosophy strategy chart (figure 4-6) shows that where collective and personal risk is high, Safe System Transformation Works are likely to be the most effective in producing significant step change in the safety profile for that section of road. In this case, a treatment like a review of the speed limit alone may not necessarily be the most effective strategy as it may not achieve the efficiency, function and user expectations of the road. However, regardless of the function of the road, consideration must be given to applying interim treatments (such as speed management initiatives like harm reduction speeds) where there is risk. Where one of the risk metrics is lower (collective, personal or RPS), then other approaches such as Safer Corridors and Safety Management treatments (eg centreline treatments and roadside improvements) may be more appropriate.

Note that, within the treatment philosophy strategy (figure 4-6), some measures will cross boundaries. Also note that this is a guide to the types of treatments that are the most appropriate for the level or risk. It does not mean we should discount all options and treatments when determining the best measures for our site or route. Cost–benefit analysis needs to be undertaken and the most cost-effective treatments considered. This guide offers a range of countermeasures for various issues and good judgement should be applied.

Also note that, even though the focus of this guide is the treatment of high-risk rural roads with Safe System infrastructure measures (mostly engineering-type works), consideration needs to be given to ensure that other Safe System initiatives are considered, in particular speed management and safer road use projects.

6.2.1 Safe System transformation treatments

This section focuses on Safe System transformation treatments. These are likely to address high percentages of the fatal and serious crashes of the three key crash types for rural roads. Safe System treatments are generally the higher cost infrastructure countermeasures and are developed and implemented over a longer term; however, they can also include speed reduction measures. A summary of the types of countermeasures are included in table 6-1. Detailed information on countermeasures for Safe System Transformation Works can be found in appendix D.

The Safe System countermeasures identified in this guide are linked to the key crash types. These are generally presented in the order of the main crash types to be addressed, ie median barriers address head-on type crashes, roadside barriers and clear zones address run-off-road crashes, and grade separation and roundabouts address intersection type crashes. However, these countermeasures are not limited to reducing only the key crash types. Where information and crash reduction figures are used from other source material, this is referenced.

TABLE 6-1 Summary of Safe System Transformation Works (crash reduction, costs, life)

Treatments	Summary of description and key facts				Appendix reference
	Description	%*	$**	L***	
Expressways	(4-laning and 2+1 treatments)	N/A	N/A	N/A	##
Median barriers	Can include flexible, semi rigid and rigid	30–100	$$	10+	D1
Wide medians	Central grassed median	25–40	$$–$$$	5–20	D2
Roadside barriers	Can include flexible, semi rigid and rigid	40–45	$$–$$$	10+	D3
Clear zone	Clear recovery zones outside carriageway for errant vehicles to recover	25–40	$$–$$$	10+	D4
Grade separation	Can be in the form of an overpass or interchange	40–60	$$$	25+	D5
Roundabouts	Typically high-speed rural roundabouts	50–70	$$–$$$	25+	D6
Speed management	Applying harm reduction or harm minimisation speeds (with associated enforcement)	Various#	$$	5–20	D7

* Potential crash reduction

** Potential cost–$ ≤ $50,000 per km or low cost, $$ = $50,000 to $500,000 per km or medium cost, $$$ = $500,000+ per km or high cost

*** Treatment life (years)

\# Refer to figure 2-1 to determine reduction in injury, fatal and serious crashes from changes in speed.

\## Although these are treatment strategies, they are not defined further within the countermeasures section as they are an overall concept rather than a specific countermeasure.

6.2.2 Safer Corridor improvements

Safer Corridor improvements are those that are medium to low cost and can be implemented in a relatively short timeframe. It is important that safety improvements implemented on New Zealand roads are consistent along the corridors as much as possible, and consistent with the Safe Roads and Roadsides infrastructure objectives.

As with the Safe System treatments, this section on Safer Corridor measures follows those treatments that address head-on (eg line marking), run-off-road (eg line marking, edge marker posts and other delineation treatments) and intersection (eg speed-activated warning signs) type crashes. However, these countermeasures are not limited to reducing only the key crash types. A summary of the types of countermeasures is included in table 6-2. Detailed information on countermeasures for Safer Corridors can be found in appendix E.

TABLE 6-2 Summary of Safer Corridor treatments (crash reduction, costs, life)

Treatments	Summary of description and key facts				Appendix reference
	Description	%*	$**	L***	
Delineation (midblock)					E1
Line marking	Edgeline or centreline painted markings	25–40	$	1–5	E1.1
Edge marker posts (EMPs)	EMPs to indicate to the driver the alignment of the road ahead, especially at horizontal and vertical curves	15–67	$	1–5	E1.2
Curve warning	Standard curve warning signs (including chevron signs)	20–57	$	5–10	E1.3
Retro-reflective road pavement markers (RRPMs)	RRPMs or road studs ('cats eyes') use retro-reflection to improve night-time visibility	5–20	$	1–5	E1.4
ATP	Rumble strips can be provided along the edgeline and centreline of a roadway to provide an audible warning when traversed	10–42	$	5–10	E1.5
Median treatments					E2
Flush median	White diagonal lines painted in the centre of the road, normally about one car width	30–52	$	1–5	E2.1
Other median and centreline treatments^	A central marked area, normally narrower than typical flush median. Does not necessarily contain diagonal lines	20	$	5–10	E2.2
ATP – centrelines~	Audio-tactile no-passing lines	12–44	$	4–10	E2.3
Seal widening					E3
Lane widening	The typical rural road lane varies in width from 2.5m to 3.5m in New Zealand. There are many instances where a narrow lane increases head-on and run-off-road type crashes	5–19	$$	10+	E3.1
Shoulder widening	A sealed shoulder provides drivers with a dependable surface to regain control of an errant vehicle	14–35	$$	10–20	E3.2
Passing lanes					
Passing lanes	Also known as overtaking lanes. Includes slow vehicle bays	10–33	$$	10	E4
Geometry					E5

Consistent super-elevation	Super-elevation (crossfall/ camber) is applied to a road for drainage and to improve centripetal force	40–50	$$-$$$	10+	E5.1
Curve radius and alignment consistency	The crash rate for curves increases as the difference between curve negotiation speed and approach increases	See figure in E5.2	$$$	25+	E5.2
Speed management treatments					E6
Speed-activated warning sign (SAWS)	Digital signs that display a message when approached by a driver exceeding a speed threshold	35	$	5–10	E6.1
Speed thresholds	Gateway treatments that are used to indicate to a driver a change of speed environment	11–27	$	5–10	E6.2
Lower the posted speed limit	Applying harm reduction speeds (with associated enforcement)	>30% fig 2-3	$	5–10	E6.3
Hazard removal					E7
Roadside hazards – poles/trees	Power poles and trees located close to edge of road create hazards for errant vehicles	10–40	$	5–10	E7.1
Roadside hazards – open drains/steep slopes	Open drains and steep slopes located close to edge of road create hazards for errant vehicles	10–40	$-$$	5–10	E7.2

^ Wide centreline treatments are presently under trial subject to approval under the Traffic Control Devices trial process

~ Presently subject to NZTA national approval for use on state highways

* Potential crash reduction

** Potential cost-$ ≤ $50,000 per km or low cost, $$ = $50,000 to $500,000 per km or medium cost, $$$ = $500,000+ per km or high cost

*** Treatment life (years)

6.2.3 Safety Management treatments

Safety Management treatments are lower-cost measures (such as making sure what is on the road is adequate for the environment and risk) and are most appropriate on lower-volume roads where higher-cost infrastructure measures such as solid median barriers and grade-separated intersections are not feasible. Although not considered purely Safe System treatments, other lower-cost measures can still deliver substantial safety benefits.

A summary of the types of countermeasures are included in table 6-3. Detailed information on countermeasures for Safety Management can be found in appendix F.

TABLE 6-3 **Summary of Safety Management treatments (crash reduction, costs, life)**

Treatments	Summary of description and key facts				Appendix reference
	Description	%*	$**	L***	
Skid resistance enhancements					
Increased intervention levels	Minimum levels of skid resistance for roads	30–50	$-$$	3–10	F1
Intersections					F2
Auxiliary turn lanes	Auxiliary turn lanes include right and left turn lanes	25–40	$$	10+	F2.1
Sight distance	Allows drivers sufficient time with which to adapt to other road users turning in/out of intersections	28–30	$	5–10	F2.2
Controls	Either stop or give way control at intersections	15–35	$	5–10	F2.3
Variable signs and information					F3
Active signs (vehicle activated/ variable speed)	Warning signs with electronic display components that become active with hazardous activity on the road	30–35	$	1–10	F3.1
VMS	Warning signs that have electronic display components and the message can be changed	N/A#	$	10	F3.2
Vegetation					
Vegetation maintenance and planting policies	Includes trimming vegetation and providing planting policies to prevent hazard being created	10–50	$	1–10	F4

* Potential crash reduction

** Potential cost–$ ≤ $50,000 per km or low cost, $$ = $50,000 to $500,000 per km or medium cost, $$$ = $500,000+ per km or high cost

*** Treatment life (years)

Difficult to determine crash reduction percentage as there are many different forms and messages contained within a VMS

6.2.4 Safety Maintenance treatments

The Safety Maintenance treatments are generally those standards and guidelines that set the legal or minimum required standard in accordance with current specifications. This guide does not go into specific information on what is considered good maintenance practice. Local policy and guidance documents should be referenced. A summary of the types of Safety Maintenance treatments are included in table 6-4.

TABLE 6-4 Safety Maintenance treatments

Safety Maintenance	The legal or minimum required standard and in accordance with current specifications or best practice guidelines of: • skid resistance management • signs and markings • prioritisation for treatment of safety deficiencies and treatment of deficiencies using conventional 'good' maintenance practice.

The most important aspect of developing solutions is to link the specific countermeasures to the specific problems identified.

Typically, a crash reduction study has focused on low to medium cost engineering solutions such as signs and markings and minor intersection improvements. These have proven to be very effective with excellent economic returns. However, in some cases a significant crash reduction may only be achieved through larger-scale, more substantial improvements.

When developing solutions for crash clusters, all the recommended treatments in section 6 can be considered.

Further information on identifying and treating crash clusters can also be referenced from the *New Zealand guide to the treatment of crash locations*.

6.2.5 Treatments based on key crash types (themes)

As discussed in section 3 of this guide, three key crash types contribute to the majority of rural road crashes and result in fatal or serious crashes: head-on, run-off-road and intersection type crashes. We have also included crashes involving vulnerable road users because the outcomes are typically severe when pedestrians and cyclists are involved in open road crashes. This is due to the often high speeds of traffic and the human body's limited tolerance to crash forces at speeds above 40km/h (figure 2-1).

A description of how to address key crash types with Safety Management and Safer Corridor treatments is provided in this section, a summary of which is shown in table 6-5.

TABLE 6-5 Summary of key crash types' best value treatments

Key crash type	Recommended Safe System treatments	Recommended Safer Corridor treatments	Recommended Safety Management treatments
Head-on	• Median barriers (solid/semi-rigid and flexible) • Safe System speeds	• Marked median treatments • ATP markings • Improved delineation (signs and markings) • Active signs • Harm reduction speeds	• Increased intervention levels • Skid resistance • Hazard removal
Run-off-road	• Roadside barriers • Clear zones • Safe System speeds	• Wider shoulders • ATP markings • Improved delineation • Harm reduction speeds	• Increased intervention levels • Skid resistance • Planting policies • Hazard removal
Intersections	• Grade-separated interchanges or overpasses • Roundabouts • Safe System speeds	• Wider shoulders and separated turning facilities • Improved delineation • Active signs • Harm reduction speeds	• Intervention levels • Skid resistance • Improved sight visibility through various treatment
Vulnerable road users	• Separated off-road facilities • Safe System speeds	• Wider shoulders • Improved delineation • Active signs • Harm reduction speeds	• Improved sight visibility • reduce pinch points • maintain consistent shoulder width and surface quality

1 Head-on

Head-on type crashes will predominantly be reduced by providing a form of median separation through paint markings, solid islands or other median treatments such as wire rope barriers. Each of these treatments will reduce crashes by varying levels. An evaluation of flexible posts as a median treatment compared the differences in levels of safety for certain types of median treatments [10]. Each of these median treatments is discussed in more detail in appendix D.

Other low-cost measures may provide useful safety benefits to reduce these types of crashes such as widening shoulders, ATP road marking (edge and centreline), and improved signs and markings.

TABLE 6-6 Summary of median treatments and treatment philosophy

	Median treatment	Treatment philosophy*	Indicative AADT*
More safe	Median barrier	Safe System Transformation Works	>12–15,000 vpd
↓	Wide centreline treatment with ATP (possibly with flexible posts)	Safer Corridors	8,000–15,000 vpd
	ATP on (or next to) centrelines	Safety Management	5,000–8,000 vpd
Less safe	Painted yellow no-overtaking lines	Safety Management	<5,000 vpd

* not part of the TERNZ report. Added to the table

2 Run-off road

Run-off-road crashes include loss of control on bends. Both the number and severity of these crashes can be reduced by providing, in the first instance, treatments that reduce the likelihood that vehicles lose control and, if they leave the road, providing roadsides that are clear of hazards.

3 Intersections

It is somewhat more difficult to significantly reduce rural intersection crashes without major infrastructure-type treatments such as grade separation and roundabouts. Applying a Safe Speed threshold is an option under the Safe System but it must be recognised that posted speed limits should consider the function and level of safety of the road and where road users understand and comply with speed limits and drive to the conditions.

Other Safety Management measures that may help reduce speeds and crashes at intersections include dedicated turning lanes, improved sight visibility and delineation, restricted movements and therefore conflict points, and protection from or removal of hazards around the intersection to reduce the severity of crashes.

4 Pedestrians and cyclists

Speed Management (ie speed zone, harm reduction) is an option under a Safe System to reduce risk to pedestrians and cyclists but the harm minimisation speed for these users is about 30km/h which is not achievable in rural environments. So where pedestrians and cyclists are present in significant numbers, other measures to improve their safety may need to be considered.

For high-risk rural sites or routes where a significant number of pedestrians or cyclists are present consideration could be given to providing the following treatments:

- separated off-road facilities
- wider shoulders
- improved delineation/lighting
- active signs
- reduced or managed pinch points.
- visibility especially at crossing points.

6.3 Road safety action plans

Road safety action plans provide a sense of urgency, focus and commitment to mitigate road safety risks. The plans record agreed processes for local road safety risks, objectives and targets, actions, and monitoring and reviewing. Each plan is the result of collaboration by key road safety partners (eg the NZTA, local and regional authorities, NZ Police, ACC).

It is recognised that this guide is focused on engineering treatments; however, the practitioner needs to consider a range of countermeasures to address the safety issues and concerns of key stakeholders.

The road safety action plans are the primary way to coordinate education, engineering and enforcement approaches to road safety problems at sub-regional levels. These plans can be referenced for any additional information on agreed measures at sites or routes of interest or updated as a result of Safe System investigations.

7 Programme implementation, monitoring and evaluation

7.1 Introduction

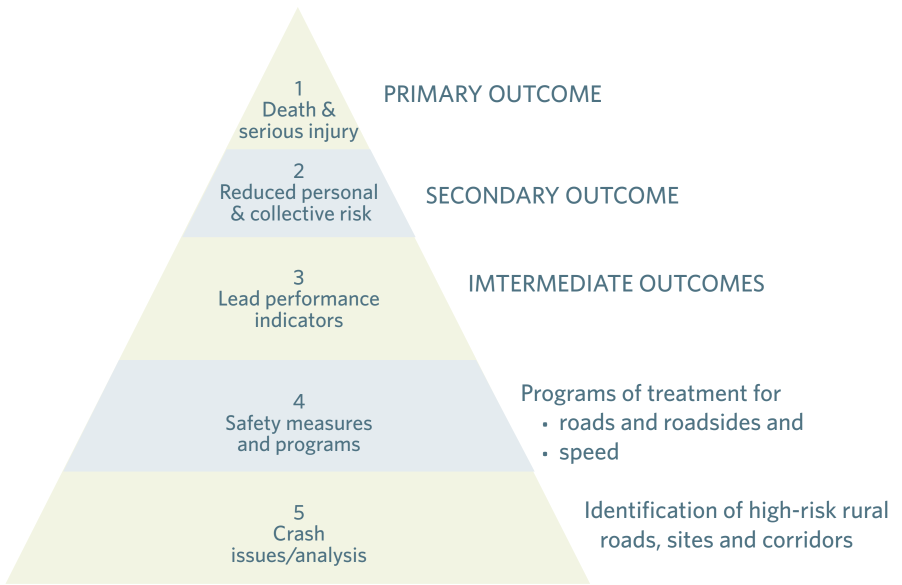
The focus of this guide is to identify high-risk rural roads and develop countermeasures that reduce fatal and serious crashes along a route or at a site. Once these routes and measures have been identified a suitable programme of implementation is important, along with a system to monitor the effectiveness of these countermeasures: 'The effectiveness of treatments guides investment in road safety programs and reliable and accurate information will be necessary to determine the effectiveness of treatments'. [127]

In this section we look at issues associated with developing programmes to treat high-risk rural routes, and then monitoring the effectiveness of those programmes to:

1. identify the benefits or rather the effectiveness of the various treatments
2. identify the most effective packages of treatments
3. assess the levels of funding that may be required to achieve various levels of crash reduction
4. 'prove' that funding has been spent wisely.

Figure 7.1 is a modified version of the safety management triangle. The foundation of this triangle is the identification and analysis of crash issues, which would include the means of identifying high-risk rural roads, corridors or sites (section 4).

FIGURE 7-1 Road safety management triangle



Having identified our sites/routes and clarified our safety concerns, this guide discusses some possible treatments or strategies that could be used to improve the safety of our high-risk rural routes, and reduce the risk of death or serious injury, the primary outcome.

In an ideal world, the analysis of the effectiveness of each treatment or programme item would be assessed by applying only one specific treatment to a range of sites and monitoring the performance of the treatment over time, before moving on to apply the next treatment. However, in New Zealand, the number of people killed or seriously injured in any one location is too small and the risk of doing nothing could be too severe – a purist approach is precluded by the delays associated with the post-implementation data collection and the immorality of 'playing with people's lives'. So in order to facilitate the necessary analysis, the road safety management triangle introduces the concept of intermediate and secondary outcomes.

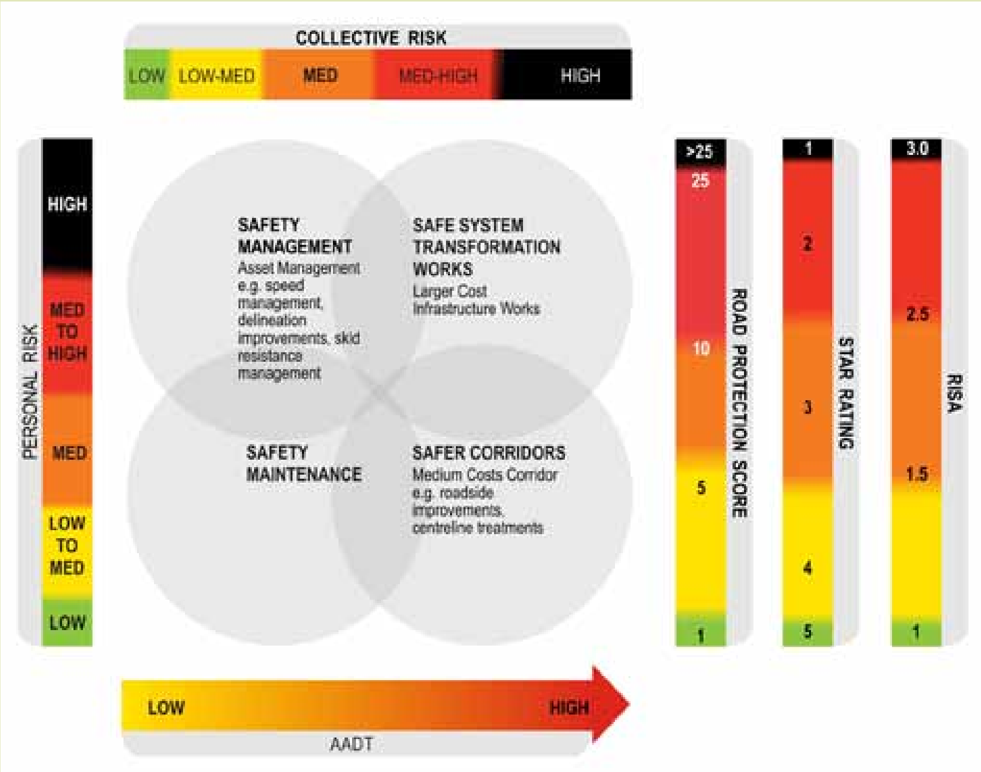
In this section we begin by looking at the development of a programme of treatments, and how to establish the appropriate intermediate measures. We then look at the monitoring site-specific secondary and primary measures.

7.2 Programme development

While the focus of the guide is on high-risk rural routes – those typically located in the upper and right side parts of figure 7-2 – it is important to remember low-cost safety management treatments still apply to the bottom left quadrant.

The assessment of rural road risks in section 4 identifies the longer-term plan for a particular rural road. Some regions will have no rural road sections in the upper and right side portions of figure 7-2, but that does not mean a programme of ongoing safety improvement should be abandoned; it just needs to be tailored to fit the appropriate end game. Analysing the data and understanding the issues are important (section 5).

FIGURE 7-2 Safety improvement strategies



7.2.1 Programme prioritisation – focus on infrastructure transformation countermeasures

The main focus for a Safe System approach to high-risk rural roads is to address fatal and serious crashes and the three key crash types. A report by Monash University [128] discusses infrastructure versus fundamental improvements, specifically with regard to the pattern of key crash types on rural roads. The most strategically important transformational countermeasures found within the literature review were as follows:

- **Crashworthy barrier system** – when used over extended lengths of high-speed rural road, barrier systems have the potential to reduce fatal and serious injuries to the occupants of errant vehicles by around 90%, with conservatively estimated benefit–cost ratios of around eight. Flexible barrier systems can address two major rural crash categories, namely single vehicle and head-on crashes, on straight or curved road sections, without the need for costly road duplication and/or geometric improvements to rural infrastructure.
- **Grade-separated interchange** – can virtually eliminate intersection crashes (potentially 100% effective) but the high cost of grade-separation makes them less attractive than some other alternatives.
- **Roundabouts** – can reduce casualty risk at intersections by between 70% and 80%, and crash costs by around 90%. In addition, they have been found to result in benefit–cost ratios of around 19 when constructed at rural intersections with a high crash record.

Although these measures cost more, they have significant benefits. It is desirable to plan for their implementation in the long term.

7.2.2 Challenges to implementation

A Safe System report [129] identified the following challenges to implementing a Safe System:

- cost, particularly in relation to the main infrastructure type countermeasures (ie roundabout, grade separation, median barriers)
- construction timeframes
- community support: it would be particularly important to gain acceptance from the community with the introduction of lower speed limits or compliance would be minimal
- inter-agency planning: there is a strong need for organisations to work together to deliver a Safe System
- incompatibility of travel modes: specific countermeasures may produce incompatibility between different road users.

7.2.3 Programme implementation

Consideration of the types of countermeasures and planning is important in providing the best possible outcome in terms of reducing the number of fatal and serious crashes along a route, site or area.

Turner, Tziotis, Cairney and Jurewicz [129] state:

> *'the timeframe for implementation of a Safe System infrastructure is an important consideration. A step process will most likely be required, and over a long term period (eg 20 years). Some initiatives can be implemented immediately, but others require longer. With a focus on longer term objectives, total cost can be divided over a larger number of years. The total costs per year may not be substantially more than amounts currently spent on safety (including through maintenance and major projects budget) although likely costs still need to be determined.'*

7.2.4 Focus on incremental improvements across network

The focus for a programme of works should concentrate on incremental improvements across networks to help achieve larger benefit–cost ratios. So what are incremental improvements?

Having identified that a route requires larger infrastructure/capital projects to produce a Safe System transformation, the end result has to some degree been confirmed. However, given the limited funding and associated priorities, together with the lead time associated with getting major infrastructure projects to construction, doing nothing until that project eventuates continues to place drivers at an increased risk of death or serious injury.

As responsible road safety practitioners and network managers, we need to consider this risk. Incremental improvements are viable if they:

- help reduce the cost of the final project, ie provide incremental benefit and costs
- return an economic road safety benefit over the intervening period, ie between now and the realistic date for delivery of the major project.

For example, the Safe System transformation of a high-volume section of highway may be the construction of a physically separated dual carriageway in 10 years. If the long-term solution will be developed on essentially the same alignment, an incremental approach could be adopted. Assuming the safety-related maintenance is being undertaken, an incremental solution could involve, in the first instance, widening sections of the carriageway where required, then installing a median barrier (1+1), improving roadside hazard management, installing passing lanes and progressively moving to a 2+1 lane arrangement, before moving to a 2+2 lane arrangement. The works undertaken at each step contribute, at least in part, to the overall Safe System Transformation Works, reducing the costs associated with the final project.

If, however, the final solution involves a completely new alignment, any proposed works will have a reduced economic life and should be analysed over the pre-implementation period.

7.2.5 Consistency and road classification

The road environment should provide the road user with strong indications about what to expect, how to behave and safe operating speeds. The consistency of road environment messages along the road corridor is important. These messages are delivered through the carriageway width, alignment, access management, signs and markings standards and other traffic control devices.

The basis for determining the service levels for both travel time and safety is the road hierarchy or, for the state highway network, the recently published state highway classification system (www.nzta.govt.nz/planning/process/state-highway.html#planning). Hence, in developing road safety programmes the road hierarchy needs to be considered and safety measures applied that are both appropriate and consistent with the road function and the traffic volumes it carries.

As well as determining the appropriateness of the safety measures, the road classification is likely to be a determinant in prioritisation for funding.

7.2.6 Driver awareness measures/self-explaining roads

Driver awareness measures for self-explaining roads provide clear direction and unambiguous information to all road users which drivers can use to make decisions and modify their behaviour depending on the design and function of a road and the associated risks. These measures are more likely on routes where there are higher levels of personal risk but low to medium levels of collective risk.

7.2.7 Communication and consultation

It is vital to engage with key stakeholders (community, affected and interested parties) when developing projects in order to create a common sense of purpose, draw on and learn from other's perspectives, make better decisions, align mutual interests, identify and mitigate risks, and find shared solutions to challenges.

Relationship building, the basis for effective engagement, takes time. Many of the hallmarks of good relationships – trust, mutual respect and understanding – are intangibles that develop and evolve over time. Early engagement provides a valuable opportunity to set a positive tone with stakeholders from the outset of a project. The absence of established relationships and communication channels can put our project at an immediate disadvantage.

Establishing and maintaining good relationships requires a long-term view. Organisations that take this approach see the value of consistently following through on their commitments to stakeholders. They take grievances seriously and deal with them in a reliable and timely manner. They continually invest in communicating about their work in a way that makes sense to their stakeholders. Effective engagement and communication will ultimately ensure the project's success. [131]

As stated within the Austroads research report 'Community Consultation Process and Methods for Quantifying Community Expectations on the Levels of Service for Road Networks AP-R290-06' [121]:

- An ideal consultation with road users and other stakeholders is one that:
  - consists of a number of clearly defined stages, each with their own specific objectives
  - includes both external stages (ie those that include road users and stakeholders) and internal stages (ie those that include employees of the road agency only)
  - is iterative in nature (ie part of an ongoing and iterative cycle of learning, refinement and improvement embedded within the development process rather than an 'isolated event' that takes place externally to it).
- The development of levels of service and intervention criteria for maintenance and improvement activities through community consultation is complex and requires careful planning. The process consists of several iterative stages: listen, communicate, reflect and plan, implement, monitor and measure. The process alternates stages that involve the community with stages that require bi-internal agency assessment and evaluation. Each stage is conducted in a structured manner and requires specific techniques and specialised skills.
- The process begins with a two-way communication ('listen' and 'communicate') between the road agency and the community with the purpose of gaining a common understanding of community concerns, priorities, current road classification system and levels of service as well as agency issues, priorities and budget limitations. This part of the process also helps develop a common language and identify the most effective channels for further communication of road maintenance issues. The two-way communication establishes the foundation for a transparent and strong relationship between the road agency and the community.

7.3 Monitoring and evaluation

Monitoring and evaluation is important in gauging the effectiveness of different Safe System treatments. This is also important when developing types of countermeasures for specific issues and implementation procedures for future programmes. Specifically:

- **Monitoring** involves an assessment of progress and collecting information through the course of a project, can be before, during and after to gather results for which to do an evaluation (section 7.3.1).
- An **evaluation** analyses the results of monitoring and determines the results and effectiveness of the types of treatments used (section 7.3.2).

7.3.1 Monitoring

Monitoring and collection of data for evaluation will help to identify if road safety has been improved: 'Systematic recording of data and analysis of trends from which goals and targets [section 7.3.3] can be calculated allows the most recent values of measures and their trends to be compared with target levels.' [130]

7.3.2 Evaluation

As stated in Austroads Report ST 1571 [127] the role of evaluation is to:

- ensure that recently delivered programmes are effective and enable remedial action if they are not
- build up a reliable knowledge base about the effectiveness of different interventions, which will allow more effective programmes to be developed in the future.

There are effectively two levels of monitoring and evaluation:

- strategically monitoring and then evaluating the effectiveness of the overall programme or strategy, which is made up of various projects or initiatives
- individually monitoring and evaluating specific projects or initiatives that make up the overall programme or strategy.

While good monitoring and evaluation will support future road safety improvement programmes, the monitoring and evaluation effort should not consume excessive amounts of staff time or other resources that could be used to undertake more road safety initiatives. As a general observation, many people and organisations undertake little or no monitoring, while others seek to monitor an extraordinary number of items, arguing that the various measures do not take account of every minute impact.

In addition, 'Only by monitoring the effects of real treatments which have been applied in real traffic situations can a reliable picture of a countermeasure's effects be obtained. Theoretical analyses form first principles and simulation provides valuable insights. The quality of an evaluation is measured by its "Validity"'[4]. The Austroads document contains detailed information on validity and general trends, changes to traffic flows, regression to the mean, crash risk mitigation and adjustment periods, which is located in section 6 of that report. Sections 7.3.4–7.3.6 summarise section 6 of the Austroads document.

In the following sections we look at the monitoring and evaluation of individual initiatives or projects and then the monitoring of the overall strategy.

1 Evaluation methods

Evaluation is essential to determine the success of individual types of countermeasures used. Any completed evaluation will help develop a future implementation programme for a Safe System. The Austroads document details information on three basic categories of evaluation of traffic studies:

- observational cross-section studies (OCS)
- observational before and after studies (OBAS)
- experimental before and after studies (EBAS).

Details regarding the various analysis statistics are not covered here but can be found in *Austroads Guide to Road Safety* 'Part 8 Treatment of Crash Locations' and include:

- chi-squared test of crash frequencies
- comparisons of crash rates using the paired t-test
- comparisons of proportions using z-test.

A summary of those studies and evaluation methods is provided in table 7-1:

TABLE 7-1 Summary of Austroads evaluation methods

Description	Study type		
	OCS	OBAS	EBAS
Description	Compare sites with and without the treatment, usually over the same period.	Compare sites before treatment installed with the same sites after treatment has been installed; treatment selection logic is as observed in the studies.	Same as OBAS, but the treatment selection is determined by the priorities and operational procedures of the RCA, ie crash history, safety improvements.
Where used	Often used where no suitable before or after data is available for the purpose of performing an evaluation.	Most commonly used for road safety evaluations.	Should be applied in addition to observational studies. Designed to control confounding factors across treatment and control sites.
Other information	Three types: Naive CS, Regression CS & Matched CS. Use control sites for comparison with treatment sites.	Three common types: Naive (simple), Before and after studies with control sites and Empirical Bayes Method.	Also known as Randomised Controlled Trials (RTC). Most effective evaluation method.
Risks	Avoid this method as it is difficult to eliminate the influencing factors which can lead to un-interpretable or seriously misleading results [4]. Potential issues include: • bias • differences in traffic volume, traffic composition and annual driving distance • differences in other relevant risk such as roads through mountains and self-selection bias.	Fundamental requirement is that the treatment introduced must retain much of the original attributes of the study site.	Key method in laboratory testing, but rarely used in road safety studies because: • treatment programmes are subject to budget constraints, and therefore only sites having the highest expected benefit–cost ratios would receive treatment priority • ethical issues arise, as it does not treat all of the high crash locations • it typically results in lower crash reduction estimates • decision makers do not understand the benefits of the RTC method.
Validity	Therefore validity depends on selecting the control sites that would have same safety performance as the treatment sites without the treatments being present.	Valid only if we can be reasonably confident that no other factors that may impact on safety apply in a biased manner. Need to account for regression to mean effects.	Eliminate all biases arising from treating sites with the worst crash history; regression to mean effects.

2 Monitoring for crash data and treatment effectiveness (CAS)

The key to effective evaluation of specific works is to ensure the data required for evaluation of individual projects, treatments or initiatives is collected over the course of the programme and staff are not faced with the arduous task of trawling back through project files to identify when and which works have been completed.

The best way of addressing this issue is to ensure the project monitoring is stepped up at the start of a project and, as discussed above, the entering of monitoring data forms part of the contract, in-house service agreement or task plan for the works. This is best done using the Crash Analysis System (CAS).

CAS is able to record three types of sites:

- **Sites of interest** (figure 7-3) – these are simply locations that users can identify spatially and for which crash data can be recalled. Once recalled the user can then analyse the effects of a programme of works. Recording works as sites of interest relies on recording key data about the works undertaken elsewhere, so sites of interest may be useful when monitoring areas to determine ongoing trends, whether these are related to improvement programmes or not.
- **Safety improvement projects or crash reduction monitoring sites** (figures 7-4 and 7-5) – these two types of site are essentially the same in terms of the inputs required. The first data entry screen (figure 7-3) allows the user to input site description data (the sites are spatially defined later in the process).

The second screen is used to identify the crash issues at the site and explicitly links the proposed solutions to the problems and the expected crash savings. While entering projects as safety improvement projects or monitoring sites involves a larger amount of more detailed data, monitoring site performance data automatically adjusts for potential regression to the mean impacts.

It is, however, important to recognise that, under the Safe System approach, we are looking toward more proactive treatment, rather than waiting for crash histories to develop, and implementing synergetic corridor treatments to increase consistency. It is therefore quite likely that in some situations works will be undertaken with a view to decreasing risks rather than to treat a documented crash history.

In such situations crash performance monitoring may well be invalid because of a lack of a 'before' crash risk. In these situations we need to monitor and evaluate our programme as a whole, or develop some other key performance measures.

FIGURE 7-3 CAS sites of interest

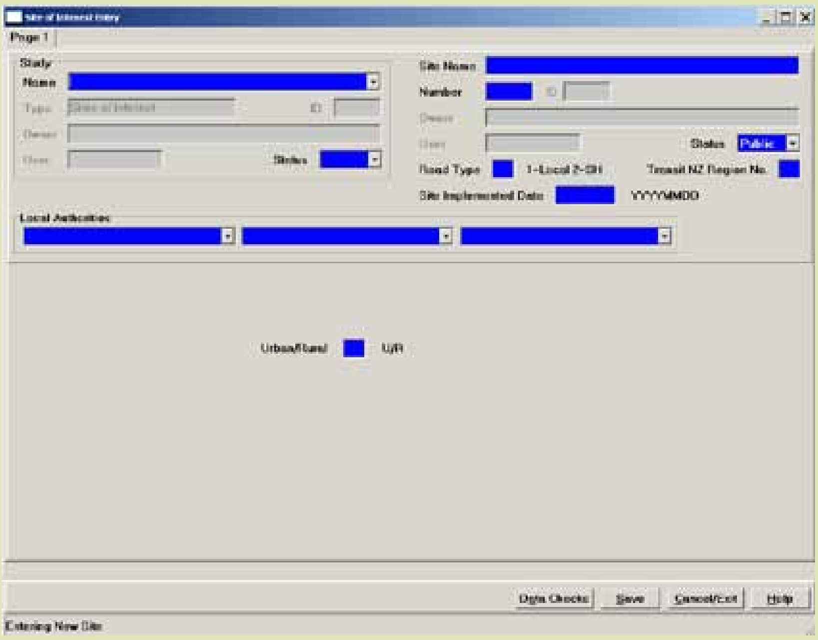


FIGURE 7-4 Monitoring site data entry screen 1

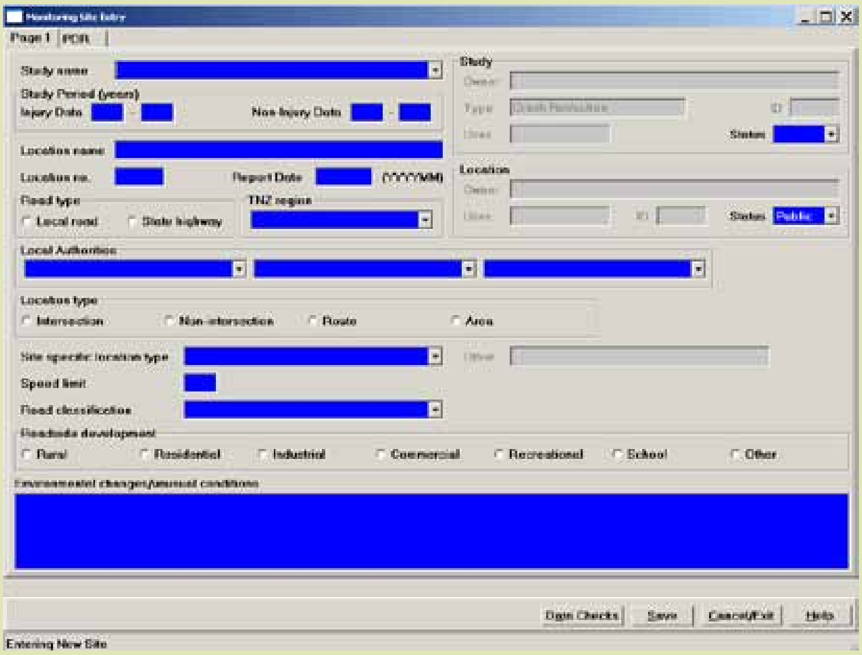
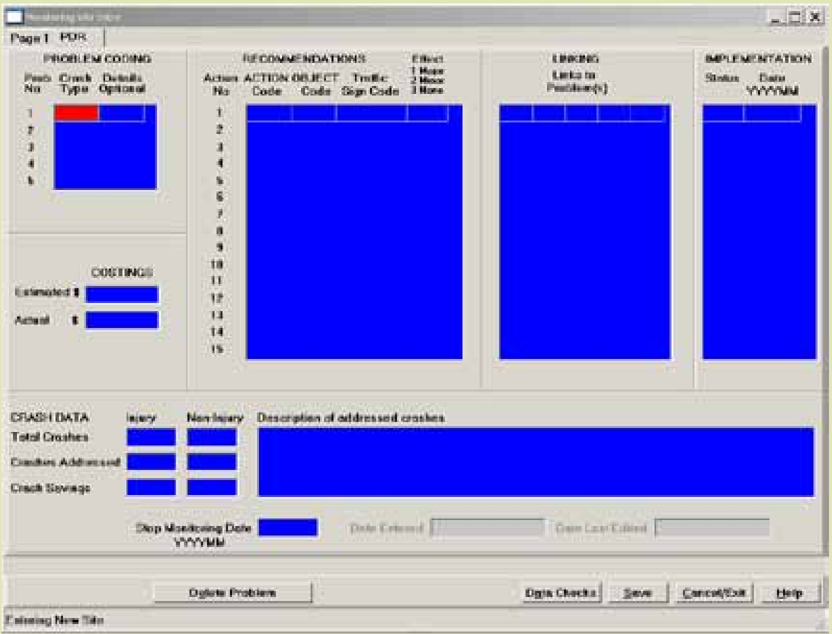


FIGURE 7-5 Monitoring site data entry screen 2



7.3.3 Monitoring and evaluation performance measures

Referring back to figure 7-1 three types of road safety measures are available for monitoring and evaluation:

- **Primary outcomes** – the reduction in the number of people killed or seriously injured as a result of road trauma.
- **Secondary outcome measures**, such as reductions in the collective and personal risk for all injury crashes. They can be measured in terms of reported crash numbers and patterns of crash types and factors. For Safer Roads and Roadside issues, reductions in predictive collective and personal risk scores are most useful. The measures can also be expressed in terms of the amount of traffic exposed to specified high-risk situations.
- **Lead performance indicators** or intermediate measures describing the improvements to the road, road environment, speed or other features that have a known impact on road safety, eg increasing the percentage of central median barriers on busier roads to reduce head-on type crashes. These output measures are known to directly impact safety outcomes.

The latter are particularly important as stated in the OECD report [5]:

> 'for a Safe System approach there is a need to switch from injury based data (final outcomes, such as traditional performance measures) to performance data (intermediate outcomes, such as lead performance indicators). Intermediate outcomes are on the basis that 100% achievement of safety performance is required in various sub targets.'

1 Primary outcomes

The primary outcome target is fewer **deaths and serious injuries** across the network.

Directly related is the reduction in fatal and serious crashes over the highest-risk routes and intersections that contribute most to the total. Where an RCA has a number of high and medium–high collective and personal risk routes, then the target could be to reduce the risk on each of these routes over a period of time.

2 Secondary outcome measures

This performance measure relates to reducing the crash risks on the network and on each high-risk rural route or intersection. Indicators could be reductions in all recorded crash types or particular subgroups such as that described in table 7-2.

TABLE 7-2 Key secondary outcome measures

Key secondary performance measures based on actual risk (crash data) could include a reduction in	Key secondary performance measures based on predictive risk analysis may include a reduction in
• number and proportion of crashes on wet roads • number and proportion of crashes in darkness • number and severity of run-off-road crashes • number and severity of head-on crashes • number and severity of intersection crashes • injuries to road user groups such as cyclists and pedestrians	• overall personal and collective predictive risk scores • predictive personal and collective risk scores for each main crash type • traffic (VKT) exposed to risk scores above a threshold • the length of route (through realignment)

3 Lead performance indicators

The smartest and most relevant lead performance indicators will relate most directly to the change in collective crash risk that is associated with improvements in the feature being assessed. Key lead performance indicators may include those listed in table 7-3.

TABLE 7-3 Key lead performance indicators

Key lead performance indicators
• Proportion of highway (or travel on highways) on roads over 12,000 vehicles per day with median barriers[15] • Proportion of highway (or travel on highways) with roadside barriers or hazard reduction[15] • Proportion of highway (or travel on highways) with lane widths of at least 3.5m. It could also include a measure of the width deficiency for each length[15] • Proportion of highway (or travel on highways) with sealed shoulder widths of at least 1m[15] • The number or percentage increase in roundabouts • The length of routes subject to speed zoning below the default limit or under active speed management • The change in network mean and/or 85th percentile speed (measured by the MoT) • The change in centreline or edgeline encroachments

15 this could include just the increase from a nominal base

For those networks for which KiwiRAP star ratings have been produced, this system provides a wealth of lead performance indicators including:

- length and travel weighted network average RPS scores
- reduction in length of, and travel on, 2 star roads.

7.3.4 Responsibilities for monitoring and evaluation

The responsibility for monitoring and evaluation at the highest level lies with the Ministry of Transport, which monitors the national trends in the numbers killed or seriously injured – the primary outcomes. However, the various RCAs should also be monitoring these primary outcomes for their respective networks. Where large networks, eg the state highway network or Auckland City, have been divided into sub-networks, the roading manager should also monitor the primary outcomes.

The various RCAs should also be monitoring the secondary outcomes, related to collective and personal risk, patterns of crash types and factors and changes in the risk profile of the routes and intersections being targeted.

RCAs will also focus on lead performance indicators as the measure of the work they are performing towards Safe System goals.

8 Other information sources/references

A number of documents and guidelines are referenced in this guide to provide more detailed information. In addition to those documents, the following web-based tools and manuals are considered good sources of road safety information for Safe System designers.

8.1 Other information

8.1.1 iRAP Road Safety Toolkit

The international Road Assessment Programme (iRAP) Road Safety Toolkit is a web-based tool that allows users to identify treatments, road users, crash types and management policies.

The Road Safety Toolkit provides free information on the causes and prevention of serious road crashes. Building on decades of road safety research, the Toolkit helps engineers, planners and policy makers develop safety plans for car occupants, motorcyclists, pedestrians, cyclists, heavy vehicle occupants and public transport users.

The Road Safety Toolkit is the result of collaboration between iRAP, the Global Transport Knowledge Partnership (gTKP), the World Bank Global Road Safety Facility and ARRB Group.

Further information can be found at www.toolkit.irap.org/

8.1.2 Austroads Road Safety Engineering Toolkit

The Road Safety Engineering Toolkit is a reference tool for road engineering practitioners. It outlines best-practice, low-cost, high-return road environment measures to reduce road trauma.

The Toolkit seeks to reduce the severity and frequency of crashes involving road environment factors. It draws together existing road safety engineering knowledge as far as possible into one Toolkit for easy access by practitioners. The presented knowledge has been updated with recent experience from Australian local and state government agencies, and with the results of comprehensive road safety research reviews.

The Toolkit is a 'living' document including updates and revisions, so that more recent safety 'wins' are captured and disseminated.

The information included in the Toolkit is based on extensive research into the effectiveness of crash countermeasures. Nonetheless, the Toolkit does not replace sound engineering judgement or good design. In-depth investigation is required at locations that have a crash history or high crash risk to identify causes or potential causes of crashes. If necessary, seek professional advice from practitioners specialising in road safety engineering. Further information can be found at www.engtoolkit.com.au/

8.1.3 KiwiRAP Assessment Tool (KAT)

The KiwiRAP star rating process captured and evaluated a range of safety engineering features on over 10,000km of rural state highways and assigned relative levels of risk based on their presence, absence or quality. This generates an RPS which in turn produces the star rating. The KiwiRAP Assessment Tool (KAT) is an interrogatable database that stores the base rated data and allows search queries to be undertaken on regions, networks and highways, or allows road sections to be identified by a range of features or feature conditions for review or comparison. KAT also allows analyses to be undertaken on the safety risk effects of altering one or more of the features. The software tool also allows the base rated data to be updated as changes occur, allowing performance monitoring of the network over time.

8.1.4 Road Infrastructure Safety Assessment (RISA)

The NZTA developed the RISA assessment to monitor an RCA's performance over time with respect to road safety. RISA provides the RCA with a tool to understand where the greatest road user benefits from improved road safety infrastructure can be gained. This guide is currently being finalised. A summary of the information can be found at www.nzta.govt.nz.

8.1.5 Rune Elvik – Handbook of Road Safety Measures

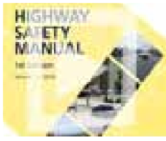
The *Handbook of road safety measures* contains summaries of the effects of 128 road safety measures. This book covers various areas of road safety including: crash reduction; the results of more than 1700 road safety evaluation studies; traffic control; vehicle inspection; driver training; publicity campaigns; police enforcement; and general policy instruments. It also covers topics such as post-crash care and speed cameras.

8.1.6 PIARC Countermeasures

This catalogue presents a set of common design errors and suggests a range of measures to overcome them;
it also indicates the comparative countermeasure costs to help prioritise the work. The catalogue can be used both as a proactive safety tool to ensure the design faults do not arise in the first place, or as a reactive safety tool to help design cost-effective countermeasures where problems already exist on the road network.

8.1.7 USA AASHTO Highway Safety Manual (HSM)

'The HSM provides tools to conduct quantitative safety analyses, allowing for safety to be quantitatively evaluated alongside other transportation performance measures such as traffic operations, environmental impacts, and construction costs.



'For example, the HSM provides a method to quantify changes in crash frequency as a function of cross-sectional features. With this method, the expected change in crash frequency of different design alternatives can be compared with the operational benefits or environmental impact of these same alternatives.' www.highwaysafetymanual.org/Documents/HSMP-1.pdf
This guide provides a number of crash modification factors and crash reduction percentages which have been used for particular countermeasures within this guide.

8.2 References

No.	Document/reference	Website information (if any)
1	Safer Journeys 2020 Strategy, Ministry of Transport, March 2010	www.transport.govt.nz/saferjourneys/Pages/default.aspx
2	Traffic Control Devices Manual, NZ Transport Agency,	www.nzta.govt.nz/resources/traffic-control-devices-manual/index.html
2a	Traffic Control Devices Rule and Traffic Note: NZ Transport Agency	www.nzta.govt.nz/resources/results.html?catid=2
3	New Zealand joint agency Road Assessment Programme (KiwiRAP)	www.kiwirap.co.nz
4	The handbook of road safety measures, Elvik, 2004	http://books.google.com/books/about/The_handbook_of_road_safety_measures.html?id=f4NUAAAAMAAJ
5	Towards Zero: Ambitious Targets and Safe System Approach, OECD, 2008	www.internationaltransportforum.org/jtrc/safety/targets/08TargetsSummary.pdf
6	OECD Report reference to P. Wramborg, 2005	www.oecd.org
7	Safe Speed thresholds for different road types, SWOV, 2008	www.internationaltransportforum.org/Pub/pdf/08TowardsZeroE.pdf
8	Economic Evaluation Manual, NZ Transport Agency, January 2010	www.nzta.govt.nz/resources/economic-evaluation-manual/volume-1/
9	Future Safe System application – Higher Speeds Roads (>80km/h) – a potential approach (Source OECD)	www.internationaltransportforum.org/Pub/pdf/08TowardsZeroE.pdf
10	'Peka Peka passing lane safe hit post median evaluation; Transport Engineering Research NZ (TERNZ) – August 2010]	www.hardingconsultants.co.nz/ipenz2011/downloads/Mackie__Hamish.pdf
11	Catalogue of design safety problems and potential countermeasures, PIARC, 2009	http://publications.piarc.org/en/search/detail.htm?publication=6047
12	Case study referenced from paper 'Longswamp to Rangiriri Wire Rope Barrier increased crash numbers but improved road safety. Crowther S, Swears, Opus International Consultants Ltd; ARRB 2010 Conference Centennial highway paper, NZ Transport Agency	www.arrb.com.au/admin/file/content13/c6/Robert_Swears.pdf
13	'Treatments > Median Barrier': International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	http://toolkit.irap.org/default.asp?page=treatment&id=13
14	'Case Studies > The Coast Road Median Barrier' International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	http://toolkit.irap.org/default.asp?page=casestudy&id=1
15	Treatment type: Safety barriers, Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=30
16	Treatment type: Median retrofit, Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=45
17	'Treatments > Roadside Safety – Barriers', International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	http://toolkit.irap.org/default.asp?page=treatment&id=28
18	Treatment type: Clear zone widening, Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=38

19	'Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes', US Department of Transportation Federal Highway Administration, 2007	www.ite.org/safety/issuebriefs/Roadway%20 Departure%20Issue%20Brief.pdf
20	Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes	www.ite.org/safety/issuebriefs/Roadway Departure Issue Brief.pdf
21	'Treatments > Intersection – Grade Separation', iRAP	http://toolkit.irap.org/default.asp?page=treatment&id=7
22	'Special Report 214: Designing Safer Roads – Practices for Resurfacing, Restoration & Rehabilitation. Transportation Research Board – National Research Council, 1987	www.scribd.com/doc/27302256/ispecial-Report-214
23	'Treatment type: Roundabouts', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=29
24	'Treatments Intersection – Roundabout', iRAP	toolkit.irap.org/default.asp?page=treatment&id=10
25	'Research Results Digest 299', National Cooperative Highway Research Program, 2005	http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_299.pdf
26	Update and Enhancement of ODOT's Crash Reduction Factors, Portland State University & Oregon State University, 2006	www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/Crash_Reduction_Factors.pdf?ga=t
27	'Speed Limits in the Safe System Concept' (source Journal of the Australasian College of Road Safety – May 2010)	www.acrs.org.au/publications/journalscurrentandbackissues.html
28	Using Police Enforcement to prevent road crashes: The Randomised Scheduled Management System; Legget; LMW	
29	'The Effectiveness of Delineation Treatments', Charlton/Baas/Towler, 2004	www.nzrf.co.nz/techdocs/conferencepapers2005/papers/The%20effectiveness%20of%20delineation%20treatments.pdf
30	'Treatments – Delineation', International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	http://toolkit.irap.org/default.asp?page=treatment&id=5
31	'Treatment type: Line marking improvements', Austroads Road Safety Engineering Toolkit,	www.engtoolkit.com.au/default.asp?p=treatment&i=73
32	'Guidelines for rural road marking and delineation RTS 5', Transit New Zealand, 1992	www.nzta.govt.nz/resources/road-traffic-standards/docs/rts-05.pdf
33	'Delineation and Hazard Markers Section 5', NZ Transport Agency, 2010	www.nzta.govt.nz/resources/motsam/part-2/docs/motsam-2-section-5.pdf
34	'Treatment type: Guide posts', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=17
35	'Treatment type: Curve warning signs', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=42
36	'Safety Evaluation of Curve Delineation Improvements Empirical Bayes Observational Before-and-After Study', Alfonso Montella,2___	http://trb.metapress.com/content/n2274g3349t04025/fulltext.pdf
37	'Treatment type: Raised reflective pavement markers (RRPMs)', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=28
38	'Delineation Improvement Cost Management Tool', TERNZ,20__	www.ternz.co.nz/DelineationCosts.xls

39	'Treatments > Rumble Strips', International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	http://toolkit.irap.org/default.asp?page=treatment&id=30
40	'Treatment type: Profile edge lines', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=24
41	'The Usability and Safety of Audio Tactile Profiled Road Markings February 2009 Research Report 365', John Edgar Consulting & TERNZ, 2009	www.nzta.govt.nz/resources/research/reports/365/docs/365.pdf
42	The cost effectiveness of delineation improvements for safety' Research Report 322, Land Transport New Zealand, 2007	www.nzta.govt.nz/resources/research/reports/322/docs/322.pdf
43	'Guidance on Design and Application of Rumble Strips', DJ Torbic, JM Hutton, CD Bokenkroger, KM Bauer, ET Donnell, C Lyon, & B Persaud, 2___	http://trb.metapress.com/content/3vj887015hg44674/fulltext.pdf
44	'Treatment type: Vehicle activated signs', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=34
45	'Assessment of Hazard Warning Signs used on New Zealand Roads' Research Report 288, SG Charlton, TERNZ Ltd & University of Waikato, 2006	www.nzta.govt.nz/resources/research/reports/288/docs/288.pdf
46	'P32 Specification for Electronic Warning Signs on State Highways', NZ Transport Agency, 2010	www.nzta.govt.nz/resources/electronic-warning-signs/docs/p32-spec.pdf
47	'Vehicle-Activated Signs – A Large Scale Evaluation', Road Safety Division, Department for Transport, MA Winnett and AH Wheeler, 2002	www.luno.se/swedish/products/VAS-Evaluation.pdf
48	'Speed change management for New Zealand roads' Research Report 300,SG Charlton, University of Waikato & TERNZ Ltd, 2006	www.nzta.govt.nz/resources/research/reports/300/docs/300.pdf
49	'Treatments > Speed Reducing Treatments', International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	http://toolkit.irap.org/default.asp?page=treatment&id=33
50	'Guidelines for urban-rural speed thresholds RTS 15' Land Transport Safety Authority, 2002	www.nzta.govt.nz/resources/road-traffic-standards/docs/rts-15.pdf
51	'Traffic Advisory Leaflet 13/93 December 1993', Department for Transport (UK), 1993	www.dft.gov.uk/adobepdf/165240/244921/244924/TAL_13-93
52	'Land Transport Rule: Setting of Speed Limits 2003', Land Transport Safety Authority, 2004	www.nzta.govt.nz/resources/rules/setting-speed-limits-2003-index.html
53	'Road Safety Risk Reporter' No. 6, ARRB Group, 2006	http://arrbcomau.ozstaging.com/admin/file/content13/c6/RiskReporter6.pdf
54	'Speed Management Summary Document', OECD, 2006	www.internationaltransportforum.org/jtrc/safety/SpeedSummary.pdf
55	'NZTA T10/2010', Davies, Cenek, Henderson, 2005	www.nzta.govt.nz/resources/skid-resistance-investigation-treatment-selection/docs/skid-resistance-investigation-treatment-selection-oct10.pdf
56	'Austroads Guide to Asset Management Part 5F: Skid Resistance', Austroads, 2009	https://www.onlinepublications.austroads.com.au/items/AGAM05F-09
57	'Treatments > Lane Widening , International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	www.toolkit.irap.org/default.asp?page=treatment&id=12

58	'Treatment type: Traffic lane widening', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=71
59	'Treatments > Shoulder Sealing', International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	http://toolkit.irap.org/default.asp?page=treatment&id=32
60	'Treatment type: Shoulder widening' and/or sealing', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=70
61	'Treatment type: Remove vegetation', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=54
62	'Treatment type: Sight distance improvements – road sections', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=58
63	'Safety deficiency: Vegetation – interference with driving task', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=issue&i=31
64	'Specification for vegetation control', Transit New Zealand, 1997	www.nzta.govt.nz/resources/vegetation-control/docs/vegetation-control.pdf
65	'Treatments Roadside Safety – Hazard Removal', iRAP; International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	www.toolkit.irap.org/default.asp?page=treatment&id=29
66	'Guidelines for Highway Landscaping – Section 2: Transit's Expectations for Highway Landscaping', Transit, 2006	www.nzta.govt.nz/resources/guidelines-highway-landscaping/docs/highway-landscaping-section-2.pdf
67	'Treatments > Central Hatching', International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	http://toolkit.irap.org/default.asp?page=treatment&id=2
68	'Treatments Central Turning Lane Full Length', iRAP; International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	http://toolkit.irap.org/default.asp?page=treatment&id=4
69	'Treatment type: Painted/flush median', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=46
70	'Treatment type: Median retrofit', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=45
71	'Install Flush Median', Land Transport Safety Authority, 1995	www.nzta.govt.nz/resources/crash-reduction/docs/flush-median.pdf
72	'Guidelines for flush medians RTS 4', Land Transport Authority, 1991	www.nzta.govt.nz/resources/road-traffic-standards/docs/rts-04.pdf
73	'Flush medians (Factsheet 52)' Land Transport Authority, Land Transport Safety Authority, 2006	www.nzta.govt.nz/resources/factsheets/52/flush-medians.html
74	'Case Studies Improved Line Marking and Rumble Strips', iRAP; International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	http://toolkit.irap.org/default.asp?page=casestudy&id=3
75	'Treatment type: Barrier lines', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=13
76	'SH1 Peka Peka passing lane will improve safety', NZ Transport Agency, 2010	www.nzta.govt.nz/about/media/releases/575/news.html
77	'Development of Crash Reduction Factors', Kentucky Transportation Centre, 1996	www.e-archives.ky.gov/Pubs/transportation/tc_rpt/ktc_96_13.pdf

78	'Treatments Intersection – Turn Lanes (Unsignalised)', iRAP; International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	http://toolkit.irap.org/default.asp?page=treatment&id=9
79	'Treatment type: Turn lanes', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=69
80	'Treatment type: Sight distance improvements – intersections', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=57
81	'Right turn treatment', NZ Transport Agency, 1994	www.nzta.govt.nz/resources/right-turn-treatment/index.html
82	'Guide to Road Design Part 4A: Unsignalised and Signalised Intersections', Austroads, 2009	www.austroads.com.au/interest_design.html
83	'Guidelines for the implementation of traffic control at crossroads RTS 1', Land Transport Safety Authority, 1990	www.nzta.govt.nz/resources/road-traffic-standards/docs/rts-01.pdf
84	'Treatment type: Give Way/Stop signs', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=63
85	'Low-cost engineering measures for casualty reduction. Application on the national road network', SV Gomes, 2___	www.ectri.org/YRS05/Papiers/Session-2bis/vieira.pdf
86	'Land Transport Rule – Traffic Control Devices 2004 Rule 54002', Ministry of Transport, 2004	www.nzta.govt.nz/resources/rules/traffic-control-devices-2004.html#10
87	'P32 Notes for Electronic Warning Signs on State Highways', NZ Transport Agency, 2010	www.nzta.govt.nz/resources/electronic-warning-signs/docs/p32-notes.pdf
88	'Traffic Note 56, Active school warning signs – Guidelines', NZ Transport Agency, 2008	www.nzta.govt.nz/resources/traffic-notes/docs/traffic-note-56.pdfhttp://www.nzta.govt.nz/resources/traffic-notes/docs/traffic-note-56.pdf
89	'Traffic Note 57, Active warning signs (not at schools) – Guidelines', NZ Transport Agency, 2008	www.nzta.govt.nz/resources/traffic-notes/docs/traffic-note-57.pdf
90	'Engineering based approaches to reducing rural speed', B Turner, ARRB Group Ltd, 2009	www.rsconference.com/pdf/RS090005.PDF?check=1
91	'Treatments > Additional Lane', iRAP: International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	http://toolkit.irap.org/default.asp?page=treatment&id=3
92	Treatment type: Additional lanes for overtaking', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=35
93	'Transit Planning Policy Manual, Appendix 3E - Passing and overtaking', Transit NZ, 2007	www.nzta.govt.nz/resources/planning-policy-manual/docs/planning-policy-manual-appendix-3E.pdf
94	'Treatment type: Superelevation improvement', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=treatment&i=19
95	'Safety deficiency: Curve – inadequate delineation', Austroads Road Safety Engineering Toolkit	www.engtoolkit.com.au/default.asp?p=issue&i=14
96	Austroads : AP-T141/10: Infrastructure/Speed Limit Relationship in Relation to Road Safety Outcomes	www.onlinepublications.austroads.com.au/items/AP-T141-10
97	Austroads: Part 8; Guide to Road Safety	www.austroads.com.au/interest_safety.html
98	IRAP website: International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility	www.toolkit.irap.org;

99	State Highway Geometric Design Manual, NZ Transport Agency	www.nzta.govt.nz/resources/state-highway-geometric-design-manual/index.html
100	Road Transport Association (RTA)	www.nzrta.co.nz/
101	David Andreasson	http://www.nationbuildingprogram.gov.au/publications/administration/pdf/Blackspot_Matrix.pdf
102	Safety Data, Analysis, and Evaluation 2009, Volume 2' research report 2103 Transport Research Board (TRB)	www.trb.org/Main/Blurbs/162222.aspx
103	Crash Modifications Clearing House	http://www.cmfclearinghouse.org/
104	RTA (2010) Delineation Section 15	http://www.rta.nsw.gov.au/doingbusinesswithus/downloads/technicalmanuals/delineation/delineationappendixaa_i.pdf
105	NCHRP Report 500: Volume 20: A Guide for Reducing Head-on crashes on freeways	http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v20.pdf
106	The cost effectiveness of delineation improvements for safety; NZTA Research Report 322	www.nzta.govt.nz/resources/research/reports/322/
107	Traffic Control Devices, Visibility, and Highway-Rail Grade Crossings 2010; Transport Research Board (TBR) research report 2149	www.trb.org/Main/Blurbs/Data_Systems_and_Travel_Survey_Methods_163904.aspx
108	ITE: Toolbox of countermeasures	www.ite.org/safety/issuebriefs/Roadway%20Departure%20Issue%20Brief.pdf
109	ITE: Toolbox of countermeasures	www.ite.org/safety/issuebriefs/Roadway%20Departure%20Issue%20Brief.pdf
110	Austroads – General	www.Austroads.co.au
111	IRAP – Central Hatching/Road marking	www.toolkit.irap.org/default.asp?page=treatment&id=2
112	Update and Enhancement of Odot's Crash Reduction Factor, Final Report 612, 2006	www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/Crash_Reduction_Factors.pdf?ga=t
113	Traffic Note 57: Active Warning Signs (not at schools) NZ Transport Agency	www.nzta.govt.nz/resources/traffic-notes/docs/traffic-note-57.pdf
114	Accident Reduction Guide, RTA Technical Direction for Road Safety Practitioners TD2004/RS01; March 2004	www.rta.nsw.gov.au/roadsafety/downloads/tds/td2004rs01_mar04.pdf
115	Austroads Technical Report 'Intelligent Transport Systems and Variable Message Signs for Road Safety Applications: Current Status and Future Prospects', AP-T133/09	www.onlinepublications.austroads.com.au/items/AP-T133-09
116	T10: 2010 Specification for State Highway Skid Resistance Management	http//nzta.govt.nz/resources/skid-resistance-investigation-treatment-selection/docs/skid-resistance-investigation-treatment-selection-oct10.pdf
117	The New Zealand Speed Zoning Policy Version 0.4.0 February 2005; NZ Transport Agency	www.nzta.govt.nz/resources/speed-limits/rural-speed-zones/
118	Australian National Road Safety Strategy (2011-2020)	www.atcouncil.gov.au/documents/atcnrss.aspx
119	ARRB: Road Safety Risk Report No. 15: Safety on rural roads: run off-road, head-on and intersection crashes; June 2011.	www.arrb.com.au/Information-services/Publications/ARRB-Newsletters.aspx
120	ARRB: Unsealed Roads Manual: Guidelines to good practice; 3rd edition, March 2009; Giummarra, G.J.	www.arrb.com.au/admin/file/content13/c6/LocalRoadsNews69.pdf
121	Community Consultation Process and Methods for Quantifying Community Expectations on the Levels of Service for Road Networks AP-R290-06	www.onlinepublications.austroads.com.au/items/AP-R290-06

122	Cenek P.D., Brodie,C.A., Davies,R.B., Tate,F.N (2011). A Prioritisation Scheme for the Safety Management of Curves 3rd International Surface Friction Conference, Safer Road Surfaces – Saving Lives, Gold Coast, Australia, 2011	www.info.opus.co.nz/about/pubs/cenek_8.pdf
123	Economic Evaluation Manual Volume 1, NZ Transport Agency	www.nzta.govt.nz/resources/search-results.html?q=economic+evaluation+manual&submit=Go
124	Jackett, MJ (1992). On which curves do accidents occur? A policy for locating advisory speed signs. Volume 1 Proceedings IPENZ Annual Conference, Christchurch, 1992, Vol. 1 (General & Civil), pp.77-84.	N/A
125	Koorey, GF, and Tate, FN (1997). Review of accident analysis procedures for Project Evaluation Manual, Transfund New Zealand Research Report No. 85, Transfund New Zealand, Wellington.	N/A
126	Turner S., Tate F. 2009. Relationship between road geometry, observed accident speed and rural accidents. NZ Transport Agency Research Report 371. 72 pp	www.nzta.govt.nz/resources/research/reports/371/docs/371.pdf
127	National Risk Assessment Model, Program Development and Trials: Interim Report 2009/10; ARRB	N/A
128	Cost effectiveness infrastructure measures on rural roads; Oxley, J; Corben B; et al, Monash University, April 2004.	N/A
129	Safe System Infrastructure – National Roundtable Report; Turner, B; Tziotis, M; Cairney, P; Jurewicz, C. ARRB Research Report AA 370	N/A
130	Austroads Guide to Road Safety Part 2: Road Safety Strategy and Evaluation	N/A
131	NZTA Effective Engagement Toolkit	N/A
132	Cycling aspects of Austroroads guides	ww.onlinepublications.austroroads.com.au/items/AP-G88-11
133	The power model of relationship between speed and safety - update and new analysis. TPI Report 1034/2009 Oslo. Rune Elvik, 2009	http://www.toi.no/getfile.php/Publikasjoner/T%D8I%20rapporter/2009/1034-2009/1034-2009-nett.pd
134	NZTA Manual of Traffic Signs and Markings (MOTSAM) part 2 (section 2.03)	www.nzta.govt.nz
135	NZTA Manual of Traffic Signs and Markings (MOTSAM) markings (part 2)	www.nzta.govt.nz
136	LTSA 'install flush median', crash monitoring summaries, March 2005	N/A
137	Davies RB, Cenek PD, Henderson RJ, The effectiveness of skid resistance and texture on crash risk	www.robertnz.net/pdf/SkidResistanceTextureCrashRisk.pdf
138	LTSA 'Right turn treatment', crash monitoring summaries, October 1994	N/A
139	NZTA VMS operating policy.	N/A
140	NZTA Traffic Note 61 'Safe System approach to rural speed management - information'	www.nzta.govt.nz

Appendices

Appendix A : RAMM SQL for calculating personal and collective risk

A user-defined table needs to be created in RAMM Manager.

To do this, open RAMM Manager. Go to Projects > User Defined Tables.

Click on Add to add a new table.

On step 1 we do not want to load any settings so click on Next.

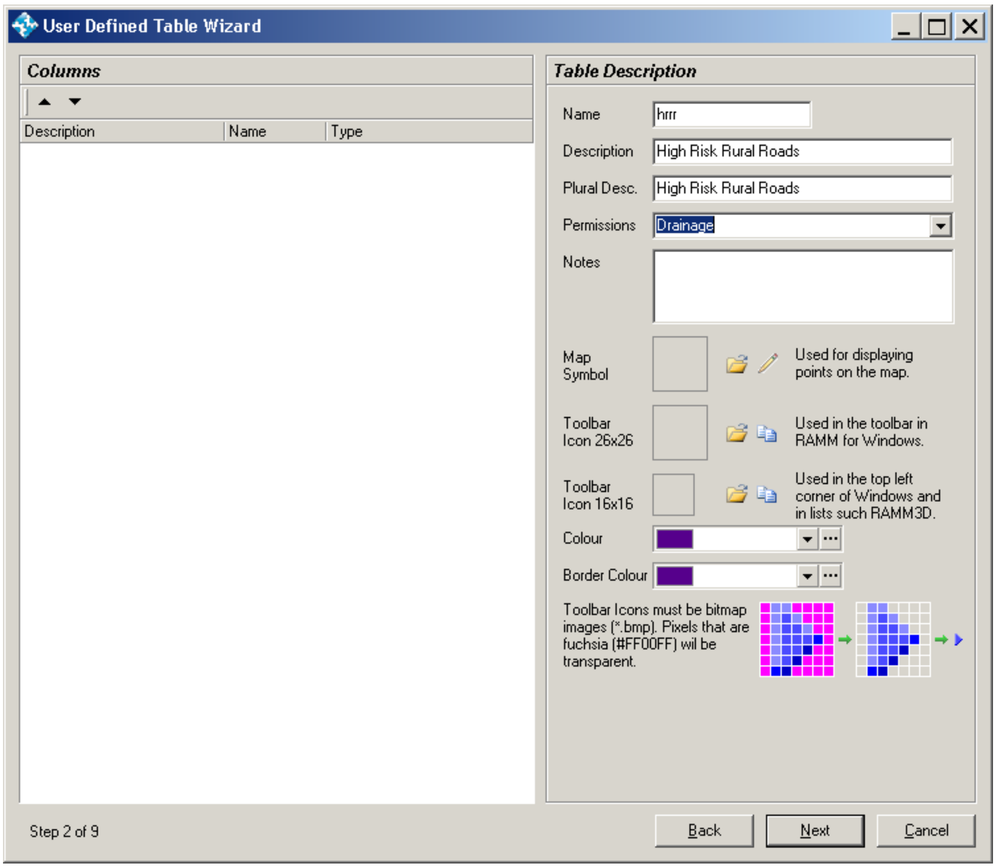
Step 2 involves naming our table.

Type (in lower case) **hrrr** in the Name field.

In the description field, type in **High-risk rural roads.**

Set the permissions to **Drainage**.

It should resemble the picture below.



Click Next to move to Step 3.

In Step 3, select **Length** and uncheck all other boxes.

Click Next to move to Step 4.

In Step 4, select **Do not include Offset** then select **Do not include a side column**.

Click Next to move to Step 5.

Click Next on Steps 5 and 6 (do not select anything).

Step 7 is the hardest step.

Add fields to the table by clicking on the New button (blank white page with a yellow + symbol) under the Custom Columns title.

The fields we need to add are described below:

Fatal Count

Name: fatal_count

Field Label: Fatal Count

Hint: Number of Fatal Crashes

Type: Integer

Default: 0

Minimum: 0

Serious Count

Name: serious_count

Field Label: Serious Count

Hint: Number of Serious Crashes

Type: Integer

Default: 0

Minimum: 0

VKT

Name: vkt

Field Label: VKT

Hint: Vehiclekm travelled

Type: Integer

Default: 0

Minimum: 0

Crash Rate

Name: crash_rate

Field Label: Crash Rate

Hint: Calculated Crash Rate (crashes per VKT millions) per year

Type: Decimal

Size: Large (16 digits, 4 decimal places)

Default: 0

Click Next to move to Step 8

Select **Asset ID** as the Description Column

Click Next to move to Step 9

Click on Finish (there's no need to Save Settings).

The table is now set up ready for data.

Before we can populate the table, we need to make sure the latest crash data has been loaded into RAMM. This step can be performed by following the instructions in RAMM Manager under **Projects -> Crash Data -> Import**

The next step is to populate the HRRR table.

RAMM SQL needs to be opened and a new query created.

The following query needs to be type in to the query screen.

```
delete from ud_hrrr;
insert into ud_hrrr (road_id, start_m, end_m, carrway_start_m)
select road_id, min(carrway_start_m), max(carrway_end_m), min(carrway_start_m)
from carr_way
where urban_rural = "R"
and owner_type = "L"
group by 1;
update ud_hrrr
set vkt = (select sum((traffic_adt_est) * ((carrway_end_m-carrway_start_m)/1000) * 365 * 5)
  from carr_way
  where carr_way.road_id = ud_hrrr.road_id
  and carr_way.urban_rural = "R")
;
select max(crash_date) max_date
from cas_crash
into temp tbl_max_date;
select *
from cas_crash c , tbl_max_date m
where crash_date > (max_date – (365.25 * 5))
into temp crash;
update ud_hrrr
set fatal_count = (select count(crash_id)
   from crash c
   where crash_fat_cnt > 0
   and ud_hrrr.road_id = c.road_id);
update ud_hrrr
set serious_count = (select count(crash_id)
   from crash c
   where crash_fat_cnt = 0
   and crash_sev_cnt > 0
   and ud_hrrr.road_id = c.road_id);
update ud_hrrr
set crash_rate = (fatal_count + serious_count)/(vkt/100000000);
```

Once we have type this in, go to the **Transaction** menu and select **Begin Transaction**

Next – click on the Run button (green triangle) below the SQL title

The table is now populated

Log into RAMM for Windows.

In the table list there will be a new table called **High-risk rural Roads**

Open this table by selecting it. On this table's window, go to **Options** and select **All Roads**

When prompted, select **All roads in the Entire Network**

We can now view / filter / sort / export all the results of the query if we want to.

To map the results, firstly open up RAMM Map (the icon looks like a pink/purple globe with white lines on it).

Next, switch back to the High-risk rural Roads window.

Go to **Actions**, then select **Add to Map -> Add to Map Now**

When the dialogue box pops up, click on the button to the left of the **Settings** box.

The **Map Settings** will appear.

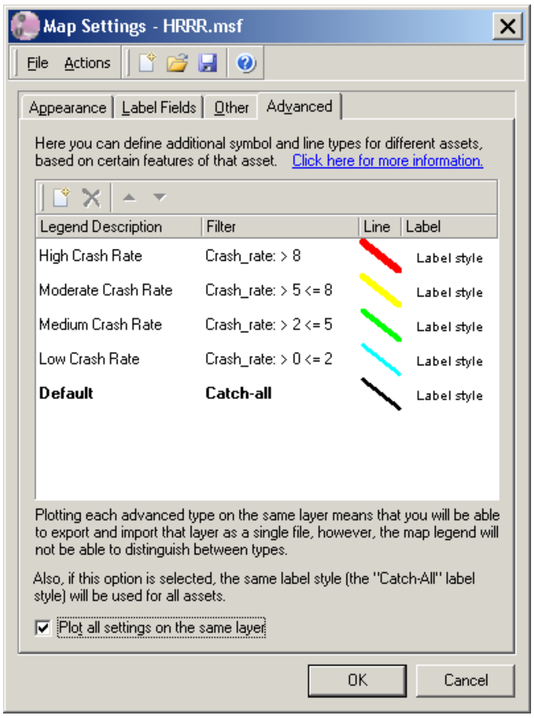
Under the **Appearance** tab, make sure only the **Line Style** box is checked

Move to the **Advanced** tab.

We can add themes to this table by adding in conditions and filters on this screen.

Click the Add button to add conditions as required.

A sample is included in the screenshot below:



Note: We need to filter on the **Crash Rate** – the higher the crash rate, the more prominent the line should be. The sample above is showing High Crash Rate (red solid line) for all roads with more than 8 crashes per 1 million VKT. We may need to change this to our local traffic environment.

Click on OK to save the settings. When prompted for save name, call it **HRRR**

We will be returned to the **Add to Map** dialogue box.

Make sure **Add all items** is selected and click OK

RAMM will now colour all the lines (as we described) according to their crash rate.

There are a number of tools to help us navigate around RAMM Map shown above the map (zoom in/out, pan, measure).

We can also alter layer settings (turn labels on/off etc) from the Layers Panel which can be accessed by clicking the button.

We can also add crashes to this map by opening the **Crash** table, selecting **All Roads**, and adding all the items to the map. Note, we may need to filter for crashes only in the last 5 years as that is what the HRRR table is using (5 years back from the latest crash date available).

Appendix B : Allocation of road networks to climate zones

CLIMATE REGION	TA NETWORKS		NZTA NETWORKS
Northern New Zealand	Far North District Whangarei District Kaipara District Rodney District* North Shore City* Waitakere City* Auckland City* Manukau City* Papakura District* Franklin District*	Thames-Coromandel District Hauraki District Waikato District Matamata-Piako District Western Bay of Plenty Tauranga City Whakatane District Kawerau District Opotiki District	Northland PSMC005 Auckland-NMMC East Waikato Bay Roads Tauranga City BOP
Central North Island	Hamilton City Waipa District Otorohanga District South Waikato District	Rotorua District Waitomo District Taupo District Ruapehu District	West Waikato Central Waikato Rotorua Dist PSMC006
Eastern North Island	Gisborne District Wairoa District Napier City Hastings District Central Hawkes Bay District	Tararua District Masterton District Carterton District South Wairarapa District	Gisborne Napier
South-West North Island	New Plymouth District Stratford District South Taranaki District Whanganui District Rangitikei District Manawatu District Palmerston North City	Horowhenua District Kapiti Coast District Porirua City Upper Hutt City Hutt City Wellington City	West Whanganui East Whanganui Wellington
Northern South Island	Tasman District Nelson City	Marlborough District Kaikoura District	Nelson Marlborough
Western South Island	Buller District Grey District	Westland District	West Coast
Eastern South Island	Hurunui District Waimakariri District Christchurch City	Selwyn District Ashburton District Timaru District	North Canterbury South Canterbury
Inland South Island	Mackenzie District Waimate District Waitaki District	Queenstown-Lakes District Central Otago District	Otago Central
Southern New Zealand	Dunedin City Clutha District Gore District	Southland District Invercargill City	Coastal Otago Southland

* = Since 1 November 2010, part of the Auckland Supercity

Proportion of rural road fatal and serious injury crashes occurring in the wet

Climate Zone	Network	All Severe Crashes	Bend – Lost Control/ Head-on	Straight – Lost Control/ Head-on	Crossing / Turning	All other Crashes
Northern New Zealand	local roads	24%	26%	23%	19%	17%
	state highways	27%	37%	19%	15%	18%
Central North Island	local roads	25%	27%	28%	20%	12%
	state highways	31%	41%	17%	26%	25%
Eastern North Island	local roads	16%	19%	4%	13%	16%
	state highways	24%	28%	17%	24%	21%
South-west North Island	local roads	23%	24%	32%	16%	5%
	state highways	28%	36%	23%	18%	24%
Northern South Island	local roads	17%	18%	8%	20%	17%
	state highways	20%	25%	17%	4%	17%
Western South Island	local roads	18%	22%	0%	0%	29%
	state highways	40%	42%	43%	33%	28%
Eastern South Island	local roads	16%	18%	21%	14%	9%
	state highways	22%	25%	21%	24%	18%
Inland South Island	local roads	21%	26%	10%	33%	13%
	state highways	18%	27%	14%	8%	6%
Southern New Zealand	local roads	32%	35%	36%	18%	22%
	state highways	36%	43%	35%	15%	29%
All New Zealand	local roads	22%	25%	23%	17%	14%
	state highways	28%	36%	22%	18%	21%

Proportion of open road fatal and serious injury crashes occurring in the dark

Climate Region	Network	Total % of high-severity crashes on open road	Bend Lost Control Head-on	Straight Lost Control Head-on	Crossing / Turning	All other Crashes
Northern New Zealand	local roads	41%	44%	49%	20%	34%
	state highways	37%	42%	37%	20%	35%
Central North Island	local roads	29%	33%	38%	8%	23%
	state highways	32%	35%	33%	20%	29%
Eastern North Island	local roads	37%	40%	47%	17%	27%
	state highways	34%	36%	35%	21%	38%
South-west North Island	local roads	36%	41%	38%	6%	32%
	state highways	36%	40%	38%	26%	33%
Northern South Island	local roads	38%	43%	42%	10%	33%
	state highways	28%	27%	40%	17%	25%
Western South Island	local roads	26%	35%	13%	0%	14%
	state highways	32%	33%	38%	0%	22%
Eastern South Island	local roads	37%	48%	49%	17%	25%
	state highways	34%	37%	41%	28%	23%
Inland South Island	local roads	33%	37%	34%	0%	13%
	state highways	33%	33%	45%	25%	24%
Southern New Zealand	local roads	36%	38%	34%	18%	41%
	state highways	34%	35%	43%	12%	31%
All New Zealand	local roads	37%	41%	43%	15%	30%
	state highways	34%	37%	38%	21%	31%

Appendix C: Using Personal reported vs predictive risk correlation charts

This appendix describes the relationship between KiwiRAP star ratings and personal crash risk, and shows how to:

- use the ratings from the KiwiRAP Assessment Tool (KAT), to estimate the personal risk of fatal and serious crashes
- use the AADT to convert the personal crash risk to a collective crash risk or crash density
- use the crash density to estimate the number of crashes on a road section and to check if the required minimum number of 3 severe crashes are predicted within the section being considered
- use estimate the potential crash reductions using KAT 'what if' analysis.

Converting KiwiRAP star ratings to personal risk (fatal and serious crashes per 100 million vkt)

Figure C-1 shows the relationship between the KiwiRAP star rating expressed to one decimal place, and the recorded injury crash rate from CAS. This is based on the data reported for each 100m section. These 1 decimal place star ratings can only be obtained from the KAT tool.

Figure C-2 provides the same relationship, but based on the published 5km KiwiRAP lengths. These 5km lengths can be broadly identified in the published documents or in NZTA spatial viewer which incidentally also gives the 5km star rating to 1 decimal place.

The relationships in the two figures are subtly different, principally because each 5km length will include some short high-risk 100m sections of highway such as intersections or isolated bends that have much worse scores than the other sections which make up the 5km length. The 100 metre relationships of figure C1 should only be used for short lengths with reasonably uniform scores.

The risk protection scores (RPSs) from which these star ratings are derived are based on research that used all reported injury crashes. From these scores the star ratings and predictive injury crash risks can be computed. (These relationships between the RPS scores, star ratings and crash rates are not linear as the graphs clearly show.) When the risk scores are converted to injury crash rates using figures C1 or C2, they are comparable to all reported injury crashes. However, this guide is principally focused on high-severity crashes (those resulting in death or serious injury), which typically make up approximately 30% of the reported injury crashes. Therefore we need to apply a 30% factor when calculating collective and personal risks to determine equivalent number of high-severity crashes for the section.

Worked example for estimating personal crash rate and equivalent high-severity crashes

A 10km section of road has a traffic volume (AADT) of 2200 vpd and a star rating of 2.6.

Estimating the equivalent personal crash rate (severe crashes per 100 million vehicle kilometres), using figure C-2 we can see that a star rating of 2.6 equates to 26 injury crashes per 100 million vehicle kilometres travelled (vkt).

To estimate the equivalent high-severity crash rates we multiply by 0.3[1] giving 7.8 severe crashes per 100 million vkt. Based on figure 4-2, this would equate to a medium–high personal risk.

1 High-severity crashes (fatal and serious) typically make up approximately 30% of the reported injury crashes

FIGURE C-1 Reported injury crash rates associated with each 1/10th star rating category, based on 100m star rating data for rated rural state highways (data for star rating categories with <2 reported injury crashes per year associated with them have been removed)

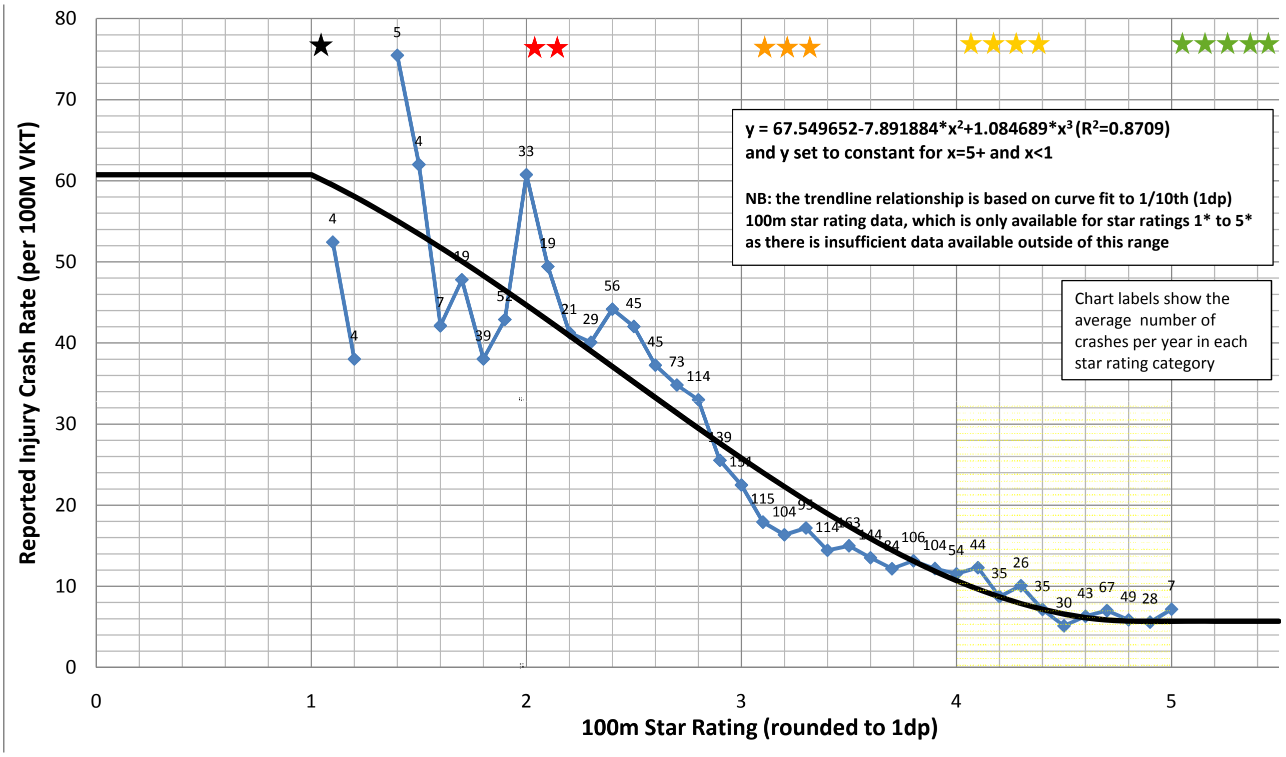
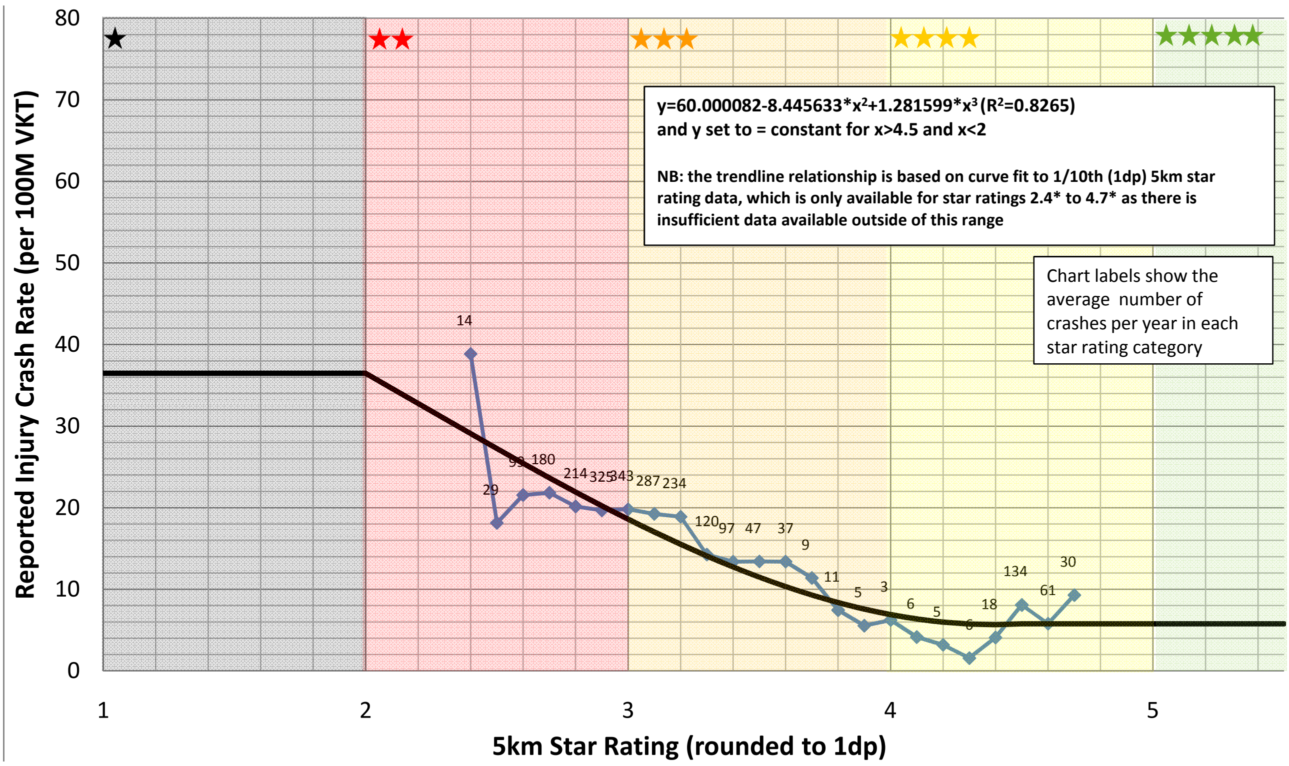


FIGURE C-2 Reported injury crash rates associated with each 1/10th star rating category, based on the published 5km star rating data for rated rural state highways



Using the previous analysis and factors we provide a worked example for **estimating the crash density** (severe injury crashes per km per year):

$$= \frac{\text{injury crash rate} * \text{AADT} * 365 \text{ (days of the year)}}{10^8}$$

$$= \frac{26 * 2\,200 * 365}{100\,000\,000}$$

= 0.21 injury crashes per km per year.

Converting to severe crash density (multiply by 30% (or 0.3)[2])

= 0.21 * 0.3 = 0.063 severe crashes per km per year.

From figure 4-1 this equates to a medium collective risk.

Estimating the number of fatal and serious crashes on a section

Estimating the equivalent number of reported injury crashes per year:

$$= \frac{\text{injury crash rate} * \text{AADT} * \text{length (km)} * 365 \text{ (days of the year)}}{10^8}$$

$$= \frac{26 * 2\,200 * 10 * 365}{100\,000\,000}$$

= 2.1 injury crashes per year

Therefore the equivalent number of potential high-severity crashes:

= 2.1 * 0.3

= 0.63 high-severity crashes per year or 3.1 severe crashes in 5 years.

This is greater than the minimum of 3 high fatal and serious crashes in five years (as defined by sections 1.2 and 4.1) needed to qualify as a high-risk rural road for funding purposes with predictive risk estimates.

Using current funding rules (section 2.4) this example uses predictive risk only, and it is therefore classified as medium strategic fit in terms of the Investment and Revenue Strategy 2011.

Estimating potential crash reductions using KAT ‘what if’ analysis

The analyst can investigate the effects of changes by using the ‘what if’ procedures of KAT. Scenarios can be developed by adjusting the raw data to reflect the changes proposed (eg coding the values for a wider road shoulder, moving roadside hazards or protecting them). KAT then calculates new RPS scores and star ratings for the lengths covered by the scenarios. Using the appropriate relationship from figure C-1 (for short lengths) and figure C-2 (for longer sections) the analyst can determine the percentage change in expected injury crashes for each scenario, and can apply it to any of the predicted values calculated above.

However this process needs to be used with caution when determining potential crash reductions. The relationships in KAT are based on research using all injury crashes. If used for treatments that are significantly effective in reducing the severity of crashes (such as Safe System measures of central and side wire rope barriers), the expected reduction figure could be quite conservative compared to what we would expect for the fatal and serious casualties.

For example, using a KAT ‘what if ‘analysis for a central median plus side barrier treatment programme along a route may improve a star rating from 3 to 3.5. When using figure C-2 we would get a 42% reduction in injury crashes (from 19 to 11 reported injury crash rate per 100 million vkt). However it is more likely that in using these Safe System treatments the reduction in fatal serious injury crashes on midblock sections would be over 70%, but minor and non-injury crashes involving collisions with a barrier may increase.

KAT ‘what if’ analysis is considered to work best for route treatments. It should not be used for intersection improvements or for isolated crash black spots.

2 High-severity crashes (fatal and serious) typically make up approximately 30% of the reported injury crashes

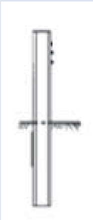
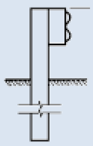
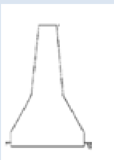
Appendix D: Countermeasures – infrastructure measures

Measure	Number
Median barriers	D1
Wide medians	D2
Roadside barriers	D3
Clear zones	D4
Grade separation	D5
Roundabouts	D6
Speed management	D7

D1: Median barriers

Description

Median barriers are generally of three types

Flexible barriers (wire rope) 	 [*Source: Google Maps 2010 Pro Licence*]
Semi-rigid barriers (typically steel beam) 	
Rigid barriers (concrete) 	

Application

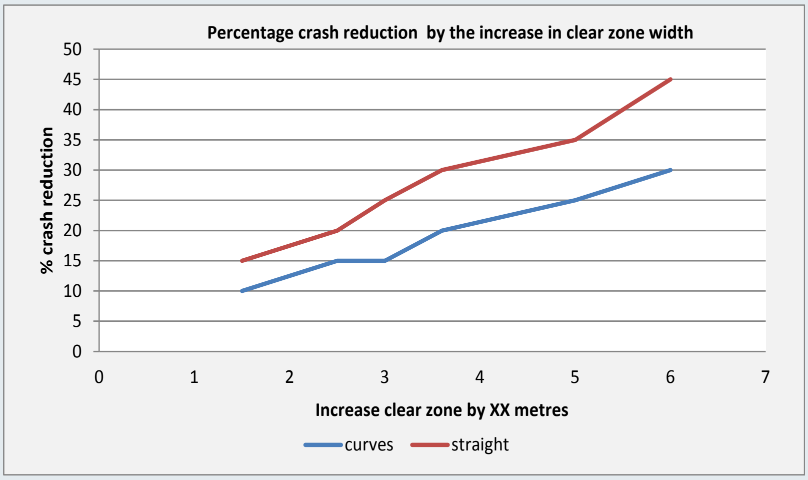
For the type of median treatments, consideration needs to be given to the traffic volumes. Where volumes are large (ie greater than 12,000–15,000 vpd) and head-on risk is high, then a wire rope barrier or solid median should be used depending on the site. Where they are between 8000 vpd and 15,000 consider wider central medians with treatments. Where they are lower than 8000 vpd then ATP markings could be used. Where they are lower than 5000 vpd, then road marking (flush medians) could be used. For routes with poor and inconsistent alignments the thresholds for considering each intervention type may be lower. Each RCA could develop their own level of treatments.

Issues

- Can restrict entry to and exit from accesses
- Restricts location of turnaround points for enforcement purposes and emergency services
- Adequate end treatments and good delineation are crucial to ensure the barrier ends do not become significant hazards
- Barriers can have significant maintenance costs that need to be compared with expected benefits
- Often requires carriageway widening and thus ancillary effects
- Consider combining with ATP markings to reduce impacts
- While all barrier types are successful with respect to head-on fatalities, rigid barriers seem to be less successful with serious injuries and minor injuries

Crash reduction	• 30% reduction in injury crashes with the installation of a median barrier on a multi-lane divided highway [16] • 40% reduction of injury crashes if installing a guardrail median barrier [16] • 30% reduction in injury crashes if installing a wire rope barrier [16] • 4–27% reduction in total crashes [11] • 51% decrease in mid-block injury crashes and 63% decrease in fatal and serious injury crashes as a result of installation of a 2+1 wire rope median barrier [12] • 100% reduction in fatal and serious crashes following installation of a 1+1 wire rope median barrier [13] • 40–60% reduction in head-on and run-off-road crashes [3]
Other benefits	Deterrent to pedestrians crossing. This can be a positive effect in situations where the location is unsafe to cross or a negative effect in locations where pedestrians desire to cross and it would be safe to cross without the barrier
Cost	$$ - $$$
Treatment life	10+ years
References and guidelines	[3],[11],[12],[13]

D2: Wide medians

Description	A wide (>9m) grassed traversable median in the centre of the road for errant vehicles to recover  State Highway 1 – Tamahere, New Zealand
Application	Used on rural high traffic volume roads with more than 2 lanes in each direction A depressed median configuration should be traversable. Median side slopes: • should preferably be ≤1:20 • should not exceed 1:10, particularly where a median barrier is installed • must not exceed 1:6
Issues	Ongoing mowing and associated traffic management costs; however if planted with frangible vegetation, it could reduce maintenance costs and these could provide a form of protection for errant vehicles. Does not totally eradicate high-speed vehicle conflicts as some vehicles still traverse the whole distance, so a barrier is still desirable. If a barrier is installed the wide space is no longer beneficial from a safety perspective and land cost can be saved
Crash reduction	A percentage reduction in crashes by increasing the clear zone width is provided in the figure below. [65] 
Other benefits	Visually more pleasing than a sealed surface with median barrier. Assist with stormwater drainage
Cost	$–$$
Treatment life	5–20 years
References and guidelines	[65], [99]

D3: Roadside barriers

Description	Roadside safety barriers include: • flexible barriers (wire rope) • semi-rigid barriers (typically steel beam) • rigid barriers (concrete). Well-designed roadside barriers reduce the severity of crashes involving errant vehicles leaving the road and colliding with more severe roadside hazards.  Side wire rope barrier, SH1 Rangiriri
Application	Traditionally, safety barriers have been developed for speed environments in excess of 70km/h, where the crash severity without a barrier outweighs the severity associated with colliding with the barrier [15]
Issues	• Safety barriers are roadside hazards. Therefore, all other options for hazard reduction should be examined before choosing to install a barrier. Barriers are designed to reduce the severity of a collision but may also increase the collision frequency because they are closer to the roadside than the hazard being protected and often extend over a longer length than the hazard being protected • Can redirect traffic back into the live traffic lane and even into opposing traffic • Length of need must be adequately calculated and designed for • Adequate end treatments are crucial to ensure the barrier ends do not become significant hazards • Barriers can have significant maintenance costs that need to be compared with expected benefits
Crash reduction	• Side barrier = 45% reduction in run-off-road injury crashes [15] • 40% reduction in total crashes [17]
Other benefits	Protection of valuable or dangerous assets on roadside Adds to the delineation of road environment, particularly on curves
Cost	$$ - $$$
Treatment life	10+ years
References and guidelines	[15], [17]

D4: Clear zones

Description

The clear zone is the space outside the road carriageway available for an errant vehicle to recover or come to a rest. Where clear zones cannot be provided, roadside safety barriers may be considered to reduce crash severity, along with measures that reduce the risk likelihood of a vehicle running off the road.

Application

- Provision of clear zones is particularly important near intersections or bends, where the complexity of the driving task and interaction with other vehicles add to the likelihood of run-off-road crashes. [18]
- Side slopes should be preferably be no steeper than 1:6 on embankments and 1:3 in cuttings.
- While full clear zone widths require in excess of 9m, the provision of 4–5m still provides significant benefits in most locations, as shown in the figure below.

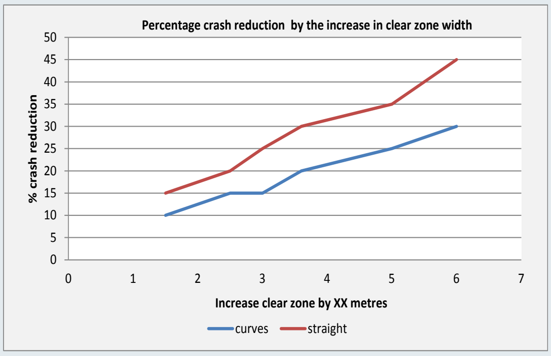
Further information on the relationship between the distance of the edge of lane and proportion of vehicles within that distance can be found in *Austroads Part 6: Roadside Design Safety and Barriers.*

Issues

- Difficult to provide in many situations as full-width clear zones require space outside most road reservations. Some situations can be high cost
- Widening the look of the road environment can create increases in operating speeds
- Comparative costs and benefits of roadside barriers should be considered as road side barriers are often more effective and less expensive.
- Creating shallow drainage ditches can sometimes create land or subsurface drainage issues
- A significant percentage of vehicles will travel beyond the design clear zone at high speed.
- Vehicles can roll as their trajectory angles increase within the clear zone

Crash reduction

- Clear zones reduce the likelihood of errant vehicles striking roadside hazards by providing clear areas for vehicles to recover
- Studies have indicated that, on high speed roads, a clear traversable width about 9m from the edge of the traffic lane allows about 80% of vehicles that run off the road to regain control [99]. The relationship between the distance from the edge of the lane and proportion of drivers/vehicles that regain control is shown in the figure below.
- A crash reduction for increasing the clear zone width by a certain amount is shown in the figure below [65].



- 25–40% reduction in run-off-road injury crashes [3]

Other benefits

Reduction in maintenance costs as roadside furniture is not hit by errant vehicles

Cost

$$

Treatment life

10+

References and guidelines

[3],[18], [65], [99]

D5: Grade separation

Description	Grade separation can be in the form of an overpass or an interchange.  
Application	Used where there is a high exposure to risk of death and serious injury through potential conflict between large volumes of through traffic and large volumes of crossing/turning traffic.
Issues	• Structures and ramps can be hazards if not correctly designed with adequate clearance, adequate merge areas, forward visibility to structures and safety devices such as guard rails. • May not be visually appealing; aesthetic design needs to be considered. • Can create community severance. • High cost • Facilities should be considered for pedestrians and cyclists.
Crash reduction	• 50% reduction of injury crashes by changing an at-grade crossroads intersection to a grade separated intersection [21] • 40–60% of intersection injury crashes [3] • 100% of intersection approaches and opposing vehicles turning type crashes [119] • 100% of adjacent approaches, and 50% of opposing turn and loss of control crashes in rural areas [119]
Other benefits	• Improved traffic flow • Reduced cost of maintaining and operating at-grade traffic control hardware
Cost	$$$
Treatment life	25+ years
References and guidelines	[3], [21], [119]

D6: Roundabouts

Description	Rural roundabouts are typically high-speed roundabouts.  Oropi Road, Western Bay of Plenty (source: Google map Pro Licence)
Application	Roundabouts generally provide a safer alternative to signalised and other unsignalised intersections. Crash reductions at roundabouts are primarily attributed to two factors: reduced traffic speeds and elimination of high-energy conflicts that typically occur at other types of at-grade intersections.
Issues	• Approach volumes and movements should be reasonably balanced to ensure all approaches function efficiently and safely • Can be difficult for heavy commercial vehicles if not appropriately designed • Not appropriate where there are high levels of pedestrians and cyclists; however, this is not usually an issue in a rural location • May require substantial land acquisition when compared with other intersection forms as a result of having to provide appropriate alignments that manage speeds. • They need to be carefully engineered with regards to high approach speeds.
Crash reduction	• Up to 70% reduction of all injury crashes in rural areas [24] • 60% reduction in intersection crashes [3] • Upgrading an intersection from a rural single-lane stop sign (T-junction) to single-lane rural roundabout reduces total crashes by 58% and injury crashes by 82% [25] • 50–70% reduction in intersections, head-on, opposing vehicles and U-turn type crashes in high-speed areas [101]
Other benefits	• Can improve traffic flow • Low maintenance requirements • Can act as threshold to complement other speed management measures
Cost	$$-$$$
Treatment life	25+ years
References and guidelines	[3], [24], [25], [101], [119]

D7: Speed management

Description	Under a Safe System, designers create and operate a transport system where road users who are alert and compliant are protected from death and serious injury. Safe Speeds are a component of the Safe System and should suit the function and level of safety of the road – road users understand and comply with speed limits and drive to the conditions. We need to consider several types of speed: • speed limits (determined by Land Transport Rule: Setting of Speeds Limits 2003) • speed zones • harm minimisation speeds • harm reduction speeds
Application	**Speed limit setting in New Zealand** The current method of calculating speed limits in New Zealand is based primarily on the level of roadside development. The higher the level of roadside development, the lower the speed limit. Some recognition is given to road geometry and facilities, but this is secondary to the development factor. This is the philosophy in Speed Limits New Zealand, which is part of the Land Transport Rule: Setting of Speed Limits 2003. Speed limits in rural areas, where there is little or no development, are 100km/h. In these areas road geometry, terrain or other operating conditions that require a driver to slow down may not be adequately explained to a driver by simply lowering the speed limit. It has been argued that correctly using warning signs, delineating or changing the road environment to meet traffic demands are better ways of managing these situations. This philosophy assumes that drivers who have sufficient information about the road geometry, terrain and other matters will make correct decisions about the safe and appropriate speed for any section of road they are driving along. [52, 118] **Speed zones** In 2004, Land Transport New Zealand (now NZTA) developed a draft speed zoning procedure that takes into account the alignment of the route and determines a speed limit based on the 85th percentile operating speed and a risk profile of the road [117]. This is in contrast to the historical and still current way to set speed limits, which is based primarily on the amount of frontage development. There is also evidence from overseas that speed limits that match the characteristics of the road contribute to a safer road environment. [118] Several trials were undertaken around the country. There was some success but also some evidence that the new limits were seen as a safe speed target by drivers who were previously travelling more slowly. **Safe System approach** As described in a paper by C Jurewicz [27], 'the Safe System approach seeks to regulate driver's speeds so that drivers respond to the level of protection offered by the road infrastructure. Under a Safe System, speed limits should be set to maximise mobility consistent with safe travel – that is, to achieve safe mobility'. Jurewicz goes on to explain that there are four principles of speed limit setting within a Safe System of which the 'prime objective is harm minimisation while maintaining mobility appropriate to road class and function'. The four principles and their application are summarised in table D-1. **Harm minimisation speeds** For each type of crash conflict there is an impact speed below which there is a low risk of severe injury. Above that impact speed threshold the risk of death or severe injury in a crash increases rapidly. The harm minimization speed in any situation is therefore determined by the type of crashes that are likely to happen. On well designed motorways with five star ratings where all crash conflicts are either eliminated or the crash forces well mitigated, the harm minimization speed may be as high as 110k m/h. (NZ has no 5 star motorways) For all other situations the harm minimization speed is set by the conflict type with the lowest threshold. For instance where pedestrians and cyclists are present or there are solid roadside features near the roadway, the harm minimisation speed is approximately 30 km/h. Research into the effects of impact speed on the severity of injuries crashes for different crash types has led to a consensus about harm minimization speed limits. They are described below in Table D-1. These speeds are generally consistent with the impact speeds at which new cars are tested in various new car assessment programmes like ANCAP. International research is continuing to understand and refine these threshold speed values. One issue is the extent to which impact speed is below travel speed for the various crash types. In many real life collisions it is apparent that there was no braking prior to impact.

	Harm reduction speeds The harm minimisation speeds are generally well below those prevailing on our rural road networks. As a consequence there is often a considerable gap between the current prevailing speeds and those of a truly safe system. It is not possible to immediately improve the network so that current prevailing speeds are safe. Hence in many situations there is a need for a compromise that also takes into account the extent to which drivers are prepared to slow down and the risk of crashes of each type - not just the severity of the consequences. These compromise speeds are called harm reduction speeds. When a speed limit is changed, the reduction in operating speed is typically much less than the change on the speed limit sign. When using figure 2-3 to estimate casualty reductions, it is the change in the mean operating speed that must be used not he change in the speed limit. As stated in Austroads [97]: 'There has been a substantial body of research published over the years relating change in speed limits to change in travel speeds and changes in crash outcomes. Understanding these relationships will assist in analysing the role of road infrastructure in changing speeds, and thus, the crash outcomes." Austroads [97] also states: 'Elvik et al. (2004) examined the magnitude of a change in mean speed associated with different speed limit changes in the sub-set of studies that evaluated such initiatives. Generally they found that the mean speed change in km/h was about one-quarter of the speed limit change (also in km/h) as shown by the slope of the line in best fit in (Figure D -1) '.
Issues	• Compliance with lower speed limits that are not usually used • Buy in from the police for enforcement purpose • Buy in from the community
Crash reduction	Crash reductions due to changes in mean speed can be estimated using figure 2-3
References and guidelines	[26], [118], [129]

FIGURE D-1 Relationship between change in speed limit and change in mean speed [96]

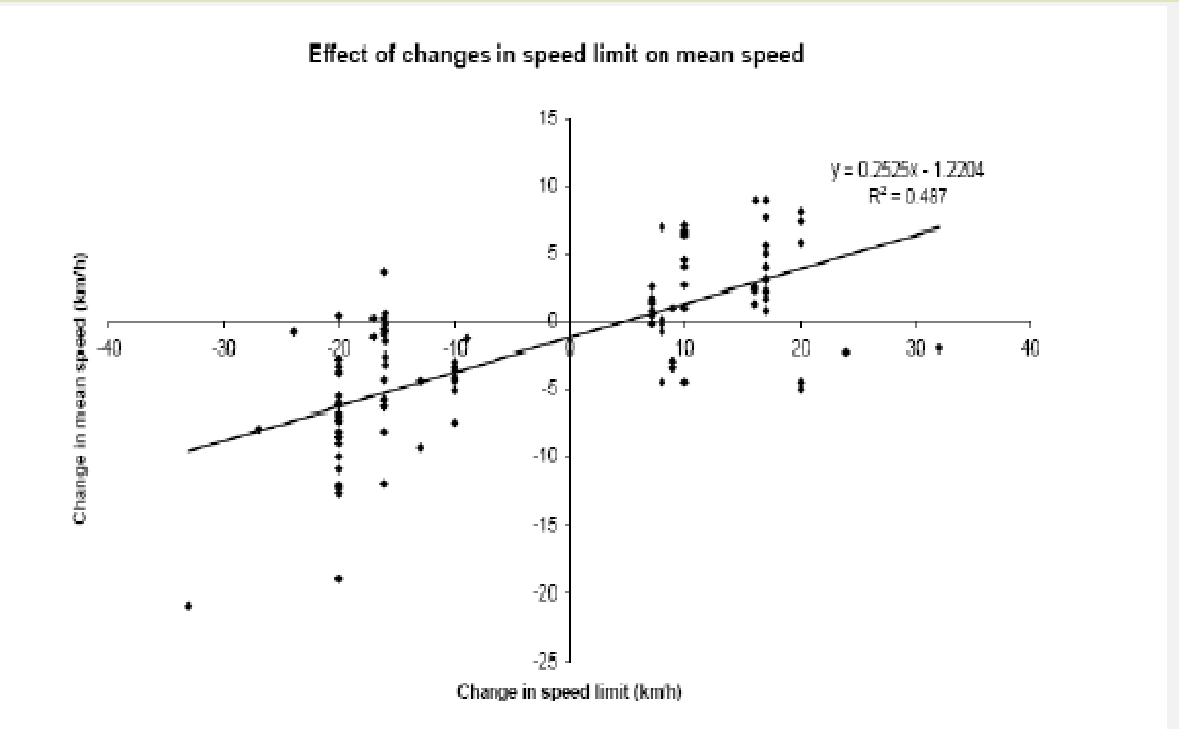


TABLE D-1 Speed limit setting principles (source; Jurewicz C. [27])

<table>
<tr><td>Mobility
What speed limit does the community expect for a given road class and function</td><td>There are a wide range of road classifications. It is important to select the mobility-based speed limit for a section of road that matches expectations already held by the community. These include:
<table><tr><th>Road class and function</th><th>Typical speed limit</th></tr><tr><td>Rural undivided roads of low design standard and urban freeways</td><td>80km/h</td></tr><tr><td>Rural arterial and sub-arterial roads</td><td>100km/h</td></tr><tr><td>Rural freeways (motorways) and arterials of high design standard (note: there are no 5 star roads in New Zealand)</td><td>110km/h</td></tr></table></td></tr>
<tr><td>Harm minimisation
What are the safe speeds for a road given the existing conditions</td><td>Involves determining the maximum speed that vehicles could travel on any road section under consideration without the occupants or other road users risking death or serious injury.
<table><tr><th>Crash type</th><th>Max. impact speed tolerance</th><th>Harm minimisation speed limit</th><th>Applicability</th></tr><tr><td>Car–motorcycle or vulnerable road user</td><td>20–30km/h</td><td>30km/h</td><td>Where vulnerable road users are present in high numbers</td></tr><tr><td>Car–tree or pole</td><td>30–40km/h</td><td>40km/h</td><td>Where unprotected road hazards exist within defined clear zone</td></tr><tr><td>Car–car (side impact)</td><td>50km/h</td><td>50km/h</td><td>Where car–car side impact is possible >50km/h</td></tr><tr><td>Car–car (head-on)</td><td>70km/h</td><td>70km/h</td><td>Where there is no separation between opposing traffic streams</td></tr></table></td></tr>
<tr><td>Gap analysis
Safe System analysis evaluation of the existing level of protection offered by the road to identify speed limit and infrastructure improvement options</td><td>Gap analysis concerns the difference between the road class and function typical speed limit, and the harm minimisation speed limit.
A selected harm minimisation speed limit may no longer be applicable if the effect of providing road safety features is expected to raise safety to the level where the revised harm minimisation speed limit matches the mobility speed limit.
The RCA needs to weigh up the capital investments for improved road features against the loss of mobility due to a lower speed limit.</td></tr>
<tr><td>Driver perception
Management of the road environment and traffic speeds if necessary</td><td>If the new speed limit is more than 10km/h lower than the existing mean speed, it is likely to require additional measures, such a road narrowing, streetscaping or planting, education, publicity and enforcement</td></tr>
</table>

Appendix E: Countermeasures – Safer Corridors measures

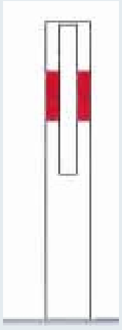
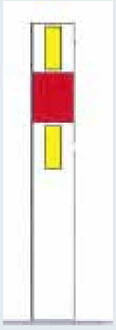
Measure	Number
Delineation	**E1**
Line marking	E1.1
Edge marker posts (EMPs)	E1.2
Curve warning	E1.3
Reflective raised pavement markers (RRPMs)	E1.4
Audio tactile profiled (ATP) edgelines	E1.5
Median treatments	**E2**
Flush median	E2.1
Other median and centreline treatments	E2.2
Audio tactile profiled (ATP) centrelines	E2.3
Seal widening	**E3**
Lane widening	E3.1
Shoulder widening	E3.2
Passing lanes	**E4**
Geometry	**E5**
Consistent super-elevation	E5.1
Curve radius and alignment consistency	E5.2
Speed management	**E6**
Speed-activated warning signs (SAWS)	E6.1
Speed thresholds	E6.2
Lower the posted speed limit	E6.3
Hazard removal	**E7**
Roadside hazards – poles/trees	E7.1
Roadside hazards – open drains/steep slopes	E7.2

E1: Delineation

E1.1: Line marking

Description	This item refers to simple painted edgelines and centrelines. For audible tactile edge lines refer to section E1.5. For other central treatments refer to section E2  Marking and re-marking painted line markings can have numerous benefits: • Centrelines can discourage overtaking and drifting from the lane and reduce head-on type crashes by shifting lane position • Edgelines can reduce run-off-road crashes and sealed shoulder damage
Application	Centrelines • Should be used where a road is greater than 5m wide and minimum AADT of 250 vpd [32] • May be marked on a road that is wider than 5.1m with a centreline [2a] Edgelines • May be marked if it is desirable [2a] • Shall be used where the seal width is greater than 7.4m or the seal width is greater than 6.6m and the AADT is greater than 750vpd [2] • Should be marked where seal width is greater than 6m and AADT is greater than 250vpd [32]
Issues	Wide lines • Marking centrelines on narrow roads can increase travel speeds and decrease the level of safety. Marking edgelines only may be more beneficial on narrow roads • May present a hazard to cyclists and motorcyclists depending on the type, thickness, skid resistance, etc
Crash reduction	Centreline • 30% reduction in all crashes [53] • 25–40% reduction in casualty crashes [30] Edgeline • 30% reduction in crashes on curves and straights [101] • 25% reduction in loss of control crashes [29] • 8–35% reduction of total accidents [11] • Widened edgelines (200mm) in high-risk locations (such as on curves) have been shown to reduce crash rates.
Other benefits	Edgelines can reduce shoulder damage, reducing maintenance costs
Cost	$
Treatment life	1–5 years
References and guidelines	[2], [2a], [11], [29], [30], [32], [53], [101]

E1.2: Edge marker posts

Description	Retro-reflective edge marker posts (EMPs) give guidance to road users of the alignment of the road ahead, especially at horizontal and vertical curves. They form a primary aid for nighttime driving.    
Application	EMPs are to be Installed on the side of the road in the shoulder or attached to a guardrail They should be used where other sources of delineation (such as line marking) are not sufficient and cannot be correctly placed Roads with greater than 500 vpd; however, where there are unfavourable conditions they can be applied on any road [32] EMPs shall be installed on all rural state highways [33]
Issues	Maintenance costs can increase due to need for frequent cleaning, weed spraying and repair / replacement of breakages Any gaps in the sequence of EMPs reduces the overall effectiveness of the delineation Speeds may increase at night
Crash reduction	• 32–67% reduction in loss of control crashes at night [32] • 15–18% reduction in total crashes at night [32] • 30% crash effectiveness [34]
Other benefits	Nil
Cost	$
Treatment life	1–5 years
References and guidelines	[32], [33], [34]

E1.3: Curve warning

Description	Advance curve warning signs indicate the general shape and direction of a curve and may also have advisory speed plates.  Warning may also be provided at the curve by horizontal curve chevron boards which may also include advisory speeds and a series of chevron curve indicators that show the extent of long curves. For speed activated warning signs refer to section E6.1
Application	Curve warning signs are used on horizontal curves where the safe and comfortable advisory speed is such that an advisory speed sign is required as specified in part 1 section 6 of the *Manual of Traffic Signs and Markings* or where the nature of the curve is not fully apparent from the approach. The speed values need to be consistent throughout the country and especially on each route.
Issues	Vandalism, maintenance (dust on sign etc), correct placement Visibility of the chevron signs in both directions needs to be considered and a sign for one direction should not be visible to traffic travelling in the opposite direction
Crash reduction	• 25–40% reduction in run-off-road, head-on and intersection type crashes [3] • 30% reduction in crashes [45] • 40.8% reduction in crashes with the use of both curve warning and chevron signs [102] • 20–57% reduction in total crashes [11] • 25% reduction in rural night-time crashes [103]
Other benefits	Potential maintenance benefit as there would be reduced collisions with roadside furniture on the curve due to drivers being better able to read the curve.
Cost	$
Treatment life	5–10 years
References and guidelines	[3], [11], [45], [102], [103]

E1.4: Raised reflective pavement markers (RRPMs)

Description	Reflective raised pavement markers (RRPMs) or "cat's eyes" provide both near and far delineation at night. They allow the alignment of the road to be seen for a greater distance than the painted markings. In wet weather RRPMs are particularly valuable since water enhances their reflectivity 
Application	RRPMs are recommended for the centrelines of all rural roads with sealed widths of at least 6 metres carrying volumes above 1000vpd (500vpd for state highways) [32]  They may also be used at lower volumes where there are: • frequent horizontal and/or vertical or substandard curves • frequent fogs or high rainfall • high numbers of wet or night crashes Red RRPM's may be used for edge line delineation when [134] • normal roadside delineation cannot be achieved, eg. roads with lay-by areas or with environmental constraints that make it impossible to install consistently located edge marker posts. • there is a proven accident blackspot or route that requires additional night time edge delineation, • there are abrupt transitions in sealed road width that may constitute a hazard eg at a narrow bridge there is a need to improve the delineation of the outside of a right hand curve at an intersection Technical specification for their use and guidance can be found within the NZTA *Manual of Traffic Signs and Markings, Traffic control devices manual* and at www.nzta.govt.nz
Issues	• RRPMs have a large initial loss in retro-reflectivity due to factors such as abrasion and build-up of road film. This improves when wet. [104] • RRPMs can be noisy if close to residential areas – this may be a concern • Maintenance costs increase due to need for maintenance and replacement
Crash reduction	• 15–20% reduction in lost control and head-on crashes at night and during wet road conditions [32] • 6–18% reduction in total crashes [11] • 5% reduction in crashes [37] • 5.7% reduction in total crashes and a 6.2 % reduction in daytime crashes. [105]
Other benefits	Can provide audible and tactile signal when traversed by vehicle wheels
Cost	$
Treatment life	4 years (source: TERNZ)
References and guidelines	[11], [32], [37], [104], [105], [134]

E1.5: Audio-tactile profiled (ATP) markings (edgelines)

Description	ATP markings can be provided along the edgeline and/or centreline of a roadway and provide audio and tactile feedback to road users. Centreline ATP are discussed further in section E2.3. This section focuses on edgeline ATP (also known as rumble strips, profiled edgelines or audio-tactile profiled edgelines). 
Application	ATP edgeline marking may replace or supplement standard edgeline markings on sections of road where: • traffic volumes are high • there is a significant number of run-off-road crashes in which fatigue or driver inattention is identified • there are specific site problems such as poor visibility, frequent or heavy rain, or night-time crash history As run-off-road crashes resulting from fatigue or other factors can occur anywhere along a route, ATP edgelines should be installed as a corridor treatment rather than be site specific.
Issues	• May present a hazard to cyclists and motorcyclists • Should be implemented over a continuous length rather than isolated sites • Drainage may be a problem in high rainfall areas if associated with a raised long life line • The auditory effect is less noticeable for larger vehicles, especially trucks • May cause noise disturbance for adjoining land users • Adequate shoulder width is required for cyclists outside of the ATP • Maintenance costs
Crash reduction	• Average 27% reduction in crashes, 32% reduction in run-off-road crashes and 42% in fatal run-off-road crashes [41] • 10% reduction of single vehicle run-off-road crashes and 17% reduction of single vehicle run-off-road fatal crashes on rural freeways [107] • 16% reduction of single vehicle run-off-road crashes and 36% reduction of single vehicle run-off-road fatal injury crashes on rural two lane roads [107]
Other benefits	Reduced shoulder maintenance (but additional cost of rumble strip maintenance)
Cost	$
Treatment life	3–8 years
References and guidelines	[41], [104], [107], [134]

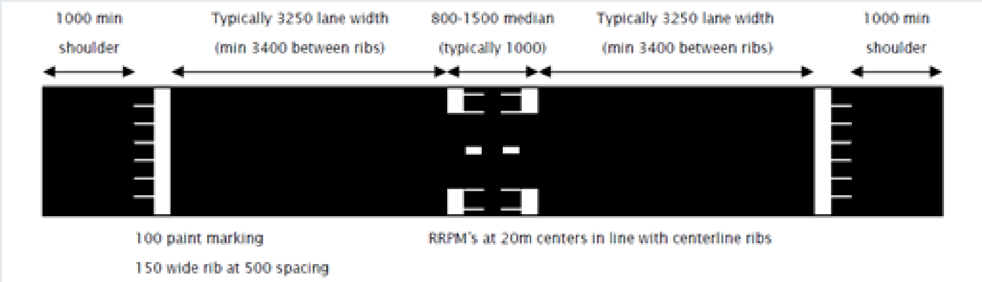
E2: Median treatments

Median treatments (as opposed to median barriers) are the lower-cost roadmarking countermeasures for the centre of the road. For median barrier treatments such as wire rope barriers and solid medians, see appendix D1.

E2.1: Flush medians

Description	Flush medians are continuous painted areas marked with white diagonal lines that are marked down the centre of the road. They provide a space clear of traffic for vehicles waiting to turn right at driveways and minor intersections. Narrow flush medians can be used simply to separate opposing traffic in a similar way to wide centrelines. Drivers are prohibited from overtaking at flush medians unless turning, unlike wide centre lines. For wide centrelines see appendix E2.2.  Rural flush median – SH27 Raungaiti
Application	Wider flush medians that provide for turning traffic may be considered for areas with frequent driveways and minor junctions that warrant speed limits up to 80 km/h. Where there is sufficient sealed width to install them without unduly compromising sealed shoulder width, narrow flush medians reduce the temptation for drivers to use them (illegally) as an overtaking lane. They may be useful where a head-on crash risk is evident or predicted.
Issues	There is potential for use of the flush median to be used as a passing lane which may lead to rear end collisions or lane change collisions where the flush median is also used as a turning lane. Where the flush median is used as an area from which to turn, sight distance needs to be considered. The space between edge lines, has to be increased to accommodate a central treatment. Depending on the site, this may reduce the shoulder width to less than the ideal.
Crash reduction	• 30% reduction in injury crashes for a narrow flush median [109] • 44% reduction in all crashes for less than 5000 vehicles per lane per day [109] • 52% reduction in all crashes for greater than 5000 vehicles per lane per day [109] • 90% reduction in fatal crashes [109] • A 47% reduction in all head-on type crashes [136] • Install flush median = 20% reduction of total casualtycrashes [111]
Other benefits	Improved flow – reduced delays if flush median is used as turning lane Provision of painted medians may result in narrowing of wide lanes, encouraging slower speeds [111]
Cost	$
Treatment life	1–5 years
References and guidelines	[19], [71], [72], [73], [109],[111], [136]

E2.2: Rural wide centrelines (trial)

Description	Rural wide centreline (trial) markings are two centrelines placed approximately 1m apart which are used to further separate opposing flows of traffic
Application	The wide centreline trial markings are still under trial and cannot be installed without NZTA approval.  (Source: NZTA Memo: 13 October 2010; centreline marking trial)  Wide centreline trial – SH3 – Rukuhia 2011
Issues	The carriageway width has to be increased to accommodate a central treatment. Depending on the site, this may reduce the shoulder width to less than the ideal.
Crash reduction	Separation will reduce head-on crashes. 20% reduction in casualty crashes [111]
Other benefits	Provision of painted medians may result in narrowing of wide lanes, encouraging slower speeds [111]
Cost	$ [111]
Treatment life	5–10 years [111]
References and guidelines	[111]

E2.3: Audio-tactile profiled (ATP) markings centrelines

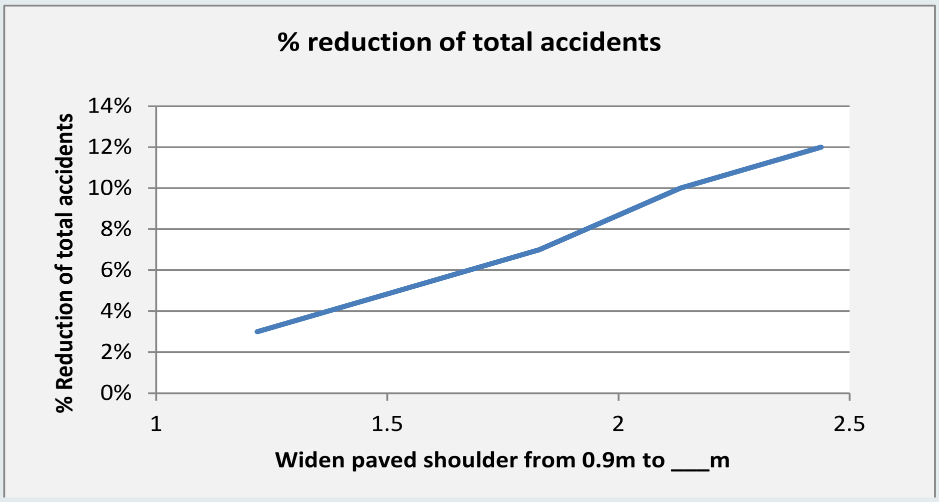
Description	This section discusses using ATP for centrelines including no passing lines. For ATP on edge lines see appendix E1.5. Centrelines and especially no passing lines are increasingly being marked with ATP to reduce head-on crash risk.  No-passing centreline with rumble strips
Application	ATP centreline marking may replace or supplement standard centreline markings on sections of road where: • traffic volumes are not high enough for median barrier treatments • a significant number of road crashes are attributed to fatigue or driver inattention • there are specific site problems such as poor visibility, frequent or heavy rain, or night-time crash history. ATP no-passing lines should be installed as a corridor treatment rather than be site specific and should be used in conjunction with profiled edgelines. White centreline ATP's are permitted. These are being used in some locations and appear to have potential to address head on crashes. However, although international research and anecdotal evidence does not identify concerns for motorcycles, further research is being completed in this regard and until the issues are better understood, white centreline rumble strips should be avoided on curvilinear routes frequented by motorcyclists. On state highways, NZTA national office approval is required.
Issues	• May present a hazard to cyclists and motorcyclists if centreline is crossed • Should be implemented over a continuous length • The auditory effect is less noticeable for larger vehicles, especially trucks • May cause noise disturbance for adjoining land users • Insufficient passing opportunities can increase travel times and frustrate drivers. Consider implementing passing lanes or sign posting upstream passing lanes • Different types have different effectiveness or wear off more quickly.
Crash reduction	• 21–37% reductions in head-on and sideswipe crashes ranging from 21% to 37% of reported crashes. [41] • On two-lane rural roads: - 12% reduction in fatal and injury crashes [107] - 44% reduction in fatal and injury head-on and sideswipe (opposite direction) crashes [107] - 25% reduction in head-on injury crashes [112]
Other benefits	Nil
Cost	$
Treatment life	1–10 years
References and guidelines	[41], [107], [112]

E3: Seal widening

E3.1 : Lane widening

Description	In New Zealand, the typical rural road lane width is 3.5m. Low volume rural roads however may have lane widths down to the legal minimum of 2.5 metres. Narrow lane widths increase the risk of head-on and run-off road type crashes. 
Application	3.5 metres is the optimum rural safe lane width so any increase beyond that brings no benefit. Only a modest increase in width such as 0.5–1.0m is usually justified. Because road shoulders are also highly beneficial the optimum allocation of sealed road space between the lane width and the sealed shoulder width should be considered. As a guide, above a lane width of about 3.3 metres, some provision for up to about half a metre of road shoulder should take priority.
Issues	• Research indicates that the safety benefits are from the overall carriageway width increase irrespective of whether it is in the lane or the shoulder. Designers need to consider (if retrofitting to an existing road) whether the benefits of an increase in lane width outweighs the dis-benefits of a reduction in shoulder width. • Can be costly due to the cost of seal widening. • Increasing lane width (with the exception of widening on curves) can increase vehicle speeds and therefore should only be used if there is an existing crash record related to narrow lane widths.
Crash reduction	• Increase from 2.7–3.0m (13%) [58] • Increase from 3.0–3.3m (19%) [58] • Increase from 3.3–3.6m (5%) [58]
Other benefits	Improved traffic flow
Cost	$$
Treatment life	10+
References and guidelines	[58]

E3.2: Shoulder widening

Description	A sealed or unsealed shoulder provides drivers with an appropriate surface on which to regain control of an errant vehicle. 
Application	• Historically we have aimed to improve highways to provide for a consistent corridor shoulder width based on standards specified according to traffic volumes. It is necessary to target seal widening to locations of greatest risk taking into account road function, crash history, alignment and roadside hazards. • Greatest benefits may come from widening on curves. Particularly on the outside of curves.
Issues	Shoulders should not be too wide (greater than about 2m) or drivers may use them as an additional lane and benefits can reduce.
Crash reduction	The greatest benefits are provided by the first 0.8 metres of sealed shoulder (30%). Increases to widths above 1 metre provide less value as shown in the figure below. • 25% casualty reduction for widening shoulder to less than 1.2m [60] • 35% reduction of casualty crashes for widening sealed shoulder to greater than 1.2m [60] • 30% reduction of casualty crashes for shoulder sealing [60] • Seal 1m shoulder (rural) [103] • 22% reduction of property damage crashes, 19% reduction in total crashes and 14% reduction of fatal, serious and minor injury accidents [103] 
Other benefits	Allows drivers to pull off-road in emergency situations or for emergency vehicle access Sealed shoulder can be used by cyclists and pedestrians. Reduces edge break and water ingress – hence lengthens pavement life.
Cost	$$
Treatment life	10–20 years
References and guidelines	[60], [103]

E4: Passing lanes

Description

This section describes passing lanes (also known as overtaking lanes) and slow vehicle bays

Application

Strategy types	Summary of passing and overtaking treatments for each strategy type A range of supporting treatments and measures are also applied, depending on strategy type	Typical 25-30 year projected traffic flow where each strategy type applies (vpd)	
		Flat road gradient	Rolling or mountainous road gradient
Overtaking	• Sight distance improvements • Overtaking enhancements • Possibly, isolated short passing lanes, slow vehicle bays, shoulder widening or crawler shoulders.	Less than 4,000	Less than 2,000
Mainly overtaking	• Sight distance improvements • Overtaking enhancements • Possibly some short "in series" (i.e. regular and frequent) passing lanes, slow vehicle bays, shoulder widening or crawler shoulders.	4,000-5,000	2,000-4,000
Passing and overtaking	• In series passing lanes. • Overtaking enhancements. • Crawler lanes, where appropriate.	5,000-12,000	4,000-10,000
Passing	• 2+1 lanes on flat/rolling road gradients (subject to comparison with four-lanes). • Passing lanes in series on mountainous road gradients.	12,000-25,000	10,000-25,000

(Source: NZTA Passing and Overtaking Policy)

Issues

Advance signage advising motorists that a passing lane is ahead will reduce the likelihood of drivers making passing manoeuvres in less safe areas.
There are areas where passing lanes should not be installed including sites which include significant intersections and access ways and sites within poor geometry immediately downstream of the passing lane.
Sight distance considerations and the length of tapers need to be considered in relation to the operating speeds. [92]

Crash reduction

- 10–25% reduction in head-on and run-off-road crashes [3]
- 25% reduction in casualty crashes [91]
- 30% reduction in head-on and 10% increase in lane change crashes with passing/overtaking lanes [92]
- 33% reduction in fatal and injury crashes [19]

Other benefits

Reduced driver frustration and stress

Cost

$$

Treatment life

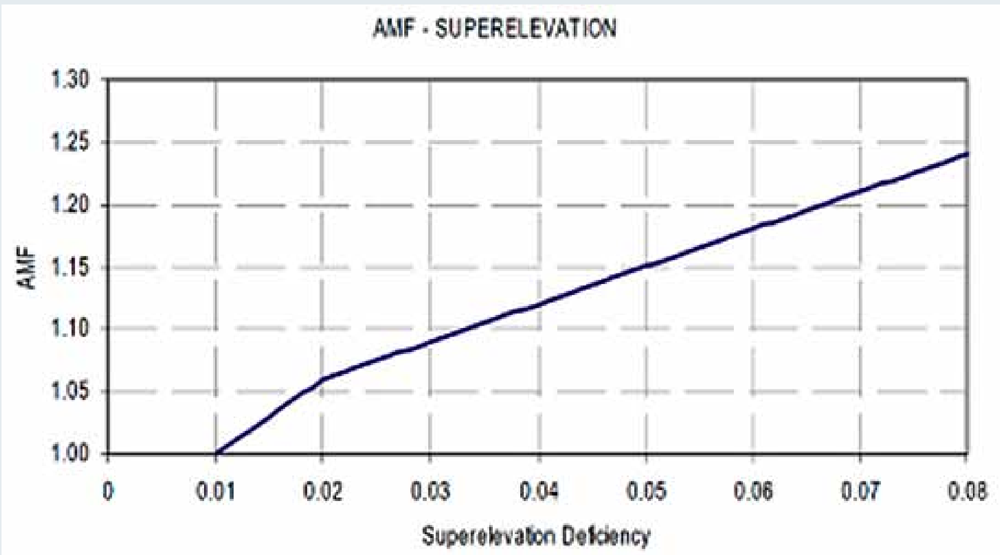
10+ years

References and guidelines

[3], [19], [91], [92],

E5: Geometry

E5.1: Consistent super-elevation

Description	Super-elevation is applied to a curve to improve the centripetal force keeping a vehicle on the road surface. Camber or crossfall refers to the normal side slope of the surface used for drainage. The following section discusses the effect super-elevation improvements can have on road safety. 
Application	Super-elevation shall be applied in accordance with Austroads guidelines. Super-elevation on curves is required where the longitudinal gradient is steeper than 8% to achieve the design speed for the road.
Issues	Super-elevation on bridges can increase construction cost of the bridge Super-elevation around curves may increase the length of drainage paths and therefore alter drainage requirements
Crash reduction	• 50% reduction in head-on, run-off-road and loss of control crashes with reconstruction of super-elevation on curve [94] • 40% for all crashes, 50% for run-off road crashes [109]  Note: AMF=accident modification factor. Crash reduction factor = 1 – AMF [112]
Other benefits	Improved drainage
Cost	$$$
Treatment life	10+ years
References and guidelines	[94], [109], [112]

E5.2: Curve radius and alignment consistency

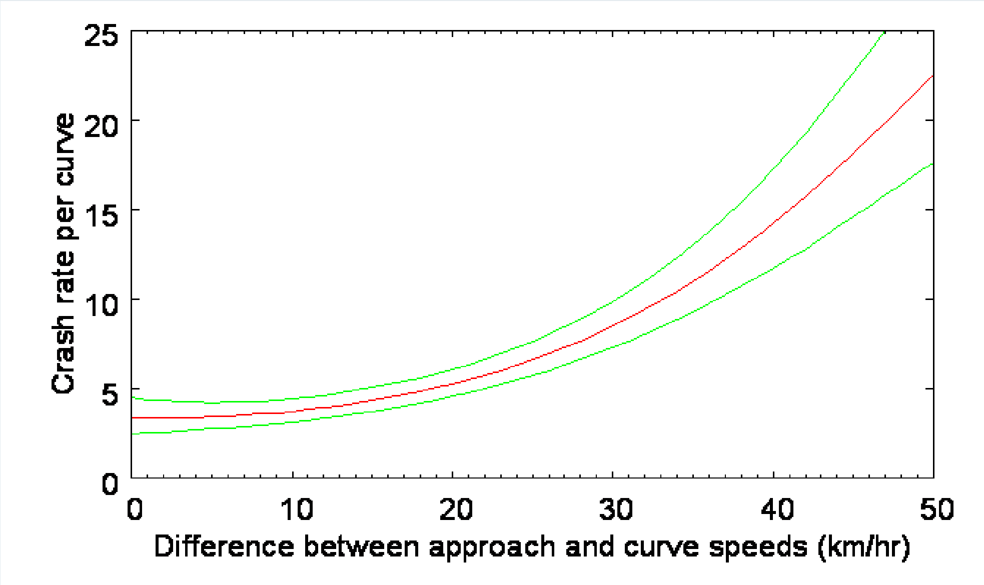
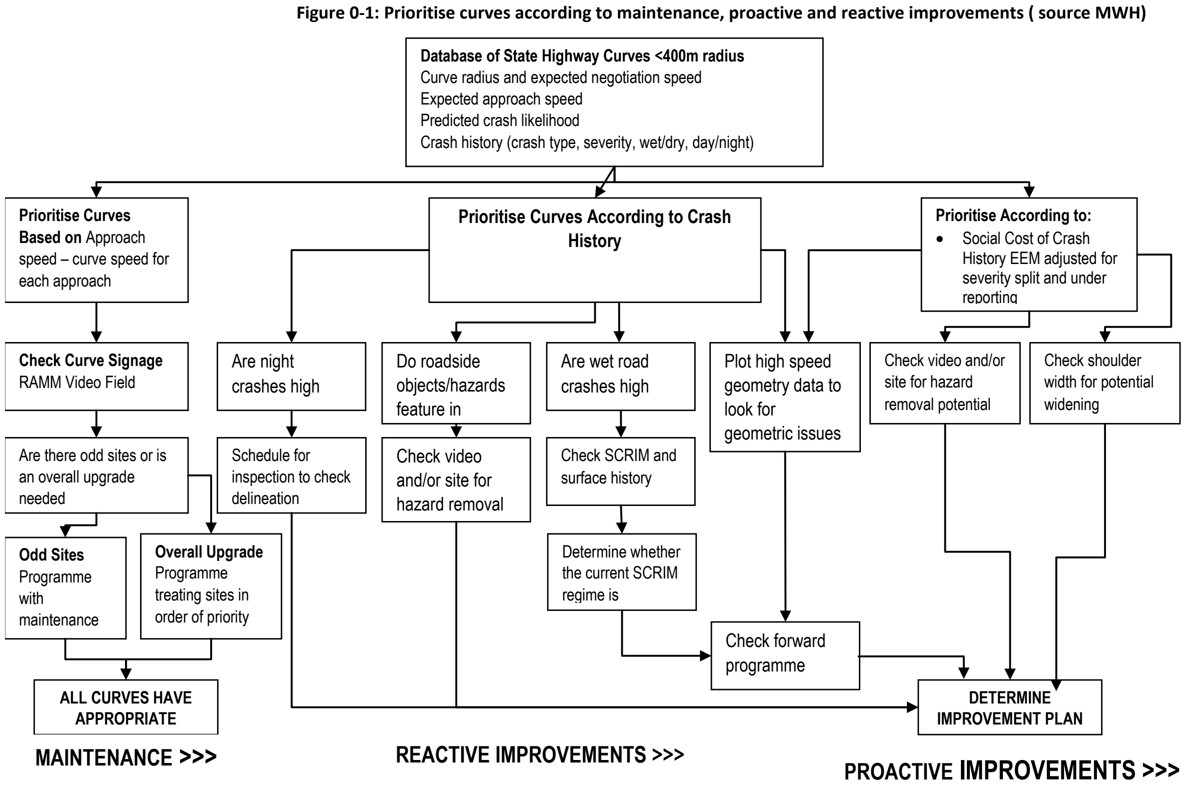
Description	New Zealand research has identified that the crashes/crash rate for curves increases with the difference between curve negotiation speed and the approach speed to the curve, typically estimated over the preceding 500m. An effective but expensive measure is to realign curves to design speeds that are consistent with the speed environment.
Application	Curve realignments can be highly effective and provide long lasting benefits. Because realignment is usually the most expensive option, the full range of other available countermeasures described in this guide need to be considered first. Analysis should determine the other factors that are contributing to the problem. These may include: limited forward visibility to the curve in question, inadequate curve warning signage, low levels of road surface friction, narrow sealed pavements, and in particular narrow sealed shoulders, and the presence of roadside hazards. Figure E1i s an example of a flow chart for developing a prioritised programme of curve improvements.
Issues	Curve easing may speed up traffic approaching subsequent curves resulting in accident migration. In addition curves at the bottom of significant downgrades will generally appear easier to negotiate and increased entry speeds can be expected.
Crash reduction	The crash reduction for curve realignment can be established using figure A6.2 in the *NZTA Economic evaluation manual* Volume 1 as it can show the potential for crash migration to subsequent curves. More recent research (Cenek et al 2011) has generated the following relationship based on a study of curves less than 400m minimum radius. 
Other benefits	Potential reduction in travel time and vehicle operating costs are a result of removing a speed change
Cost	$$$
Treatment life	25+ years
References and guidelines	[99], [122], [123], [124], [125], [126]

FIGURE E-1 Prioritise curves according to maintenance, proactive and reactive improvements (source MWH)



E6: Speed management

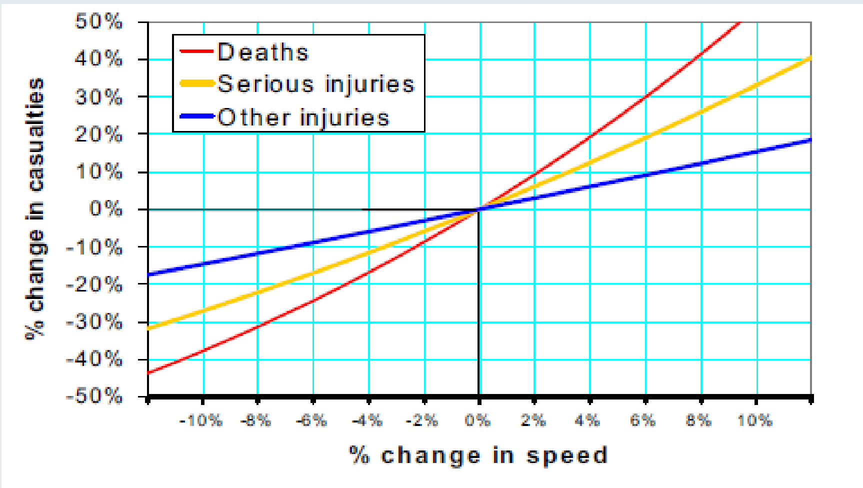
E6.1: Speed-activated warning signs (SAWS)

Description	Speed-activated warning signs (SAWS) are electronic signs that display a message when approached by a driver exceeding a speed threshold. They are typically used to warn the motorist of an upcoming hazard, eg a bend, crossroad, school or worksite.  Curve advisory SAWS (source: [46])
Application	Use to highlight and draw drivers' attention to a particular type of hazard at a site where standard reflectorised warning signs have been tried and have been found not to be sufficiently effective in warning drivers to reduce their speeds and modify their behaviour so they safely negotiate the hazardous site [113]
Issues	• Vandalism • Power supply in rural areas (solar-powered devices are available).
Crash reduction	• 35% reduction in all crashes [44] • Up to an 11km/h (7mph) reduction in speeds on approach to a curve [47]
Other benefits	Speed reduction without enforcement. SAWS can collect speed data for monitoring, although only on sign approach, not at the hazard
Cost	$
Treatment life	5–10 years
References and guidelines	[44], [46], [47], [113]

E6.2: Speed thresholds

Description	Threshold treatments (gateways) are used to alert road users of a change in speed limit or road environment. They are often used where a speed limit sign alone is not effective in ensuring driver compliance with the speed limit on the approach to a town.  source: LTSA, RTS 15, 2002. [50]  SH2, Ormond
Application	According to the guidelines for urban-rural speed thresholds [50], thresholds are a potential traffic management technique when one or more of the following conditions are present: • vehicle speeds on the town outskirts or through the urban areas are inappropriately high • all reported injury crash rates are higher than average or need to be reduced • when vulnerable road users such as pedestrians and cyclists feature in the crash analysis. They should only be installed on roads that have a difference in the warranted speed limits of 20km/h or more at the rural-urban interface.
Issues	The speed reduction produced by a threshold may dissipate within 250m if there are no downstream changes in road conditions, such as decreases in road width or an increase in urban density. [48] A threshold needs to be clearly visible with adequate sight distance to be effective. Some threshold treatments provide for cyclists around the sides of the signs, however consideration needs to be given to providing adequate space through the cycle area and whether the sealed area will be maintained.
Crash reduction	• 15–27% reduction in crashes with high visibility and physical features [48] • 11% reduction in crashes with the use of dynamic or active signs [48] • 11–20% reduction in crashes with visual narrowing treatments [48]
Other benefits	Visually appealing entrances/gateways into smaller rural towns
Cost	$
Treatment life	5–10 years
References and guidelines	[48], [50]

E6.3: Lower the posted and operating speed

Description	The default posted speed limit on New Zealand open/rural roads is 100km/h and is generally applied to all rural roads with only limited exceptions at the present time (2010). A more suitable speed limit for many of these roads might be one that more closely matches the design speed and the safety features, ie a speed that reflects Safe System harm minimisation speeds (section 2.3.3 and Appendix D7). 
Application	To lower the posted speed limit, surveys must be undertaken to first determine the current operating speed. If operating speeds are lower than the posted speed limit, then consideration could be given to implementing a speed limit determined in accordance with the draft Speed Zoning Policy for a single route or as described in Traffic Note 61 for an area treatment [117, 140]. It may be beneficial to use the derestriction sign over the 100km/h where it is not physically possible to drive at 100km/h. This leaves the choice of operating speed up to the driver rather than telling them it is a 100km/h area. When changing any speed limit, it is necessary to consult with all the affected parties as specified in the Land Transport Rule: Setting of speed Limits 2003
Issues	Where speed limits are introduced on routes where the operating speeds are higher than the new limit, then additional measures should be considered to achieve compliance. In most cases a speed limit that is not warranted is unlikely to be complied with, unless it is supplemented with engineering measures and enforcement.
Crash reduction	• For every 10km/h reduction in operating speed, a 15–40% reduction in head-on, run-off-road and intersection crashes [3] Change in posted and operating speed limit • All reductions in speed limit – 15% reduction in crashes [53] Change in operating speed • % reduction in crashes = 1 – (speed before/speed after) ^{2} [53]  Relationship between change of mean speed and crashes [118]
Other benefits	Vulnerable road users' level of safety increases with lower speed limits
Cost	$
Treatment life	5–10 years
References and guidelines	[3], [53], [54], [118], [140]

E7: Hazard removal

E7.1: Roadside hazards – poles/trees

Description

Utility poles and trees are commonly located within the clear zone on New Zealand roads. These create severe spot hazards to errant vehicles. See also appendix D4 on clear zones.

Application

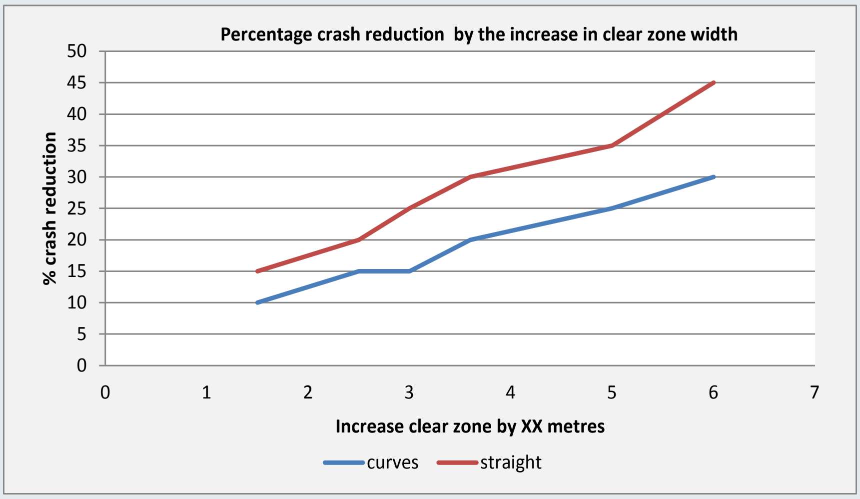
For power poles, consideration needs to be given to providing frangible poles or relocating, undergrounding, moving outside of the clear zone or providing barriers to protect road users from colliding with the pole.

Issues

- After roadside hazards are removed, the roadside should be left in a safe condition. Large stumps and deep holes are hazards that may remain after removal of a tree. [65]
- Replacement of removed trees with more appropriate plants should be considered, otherwise re-growth or soil erosion may affect the site.
- It is not always possible to remove, replace or put barriers around roadside hazards. Reducing vehicle speeds is an alternative solution. [65]
- In some Australian jurisdictions, the utility company cannot reinstate poles that have been hit (ie need for undergrounding)

Crash reduction

General removal of roadside hazards creates a reduction in run-off-road injury crashes of 25–40%. [3]
A percentage reduction in crashes by increasing the clear zone width is provided in the figure below. [65]



Providing a safety barrier to protect the hazard results in an 80% reduction in run-off-road injury crashes [97]

Other benefits

Reduced maintenance costs if not being hit

Cost

$-$$

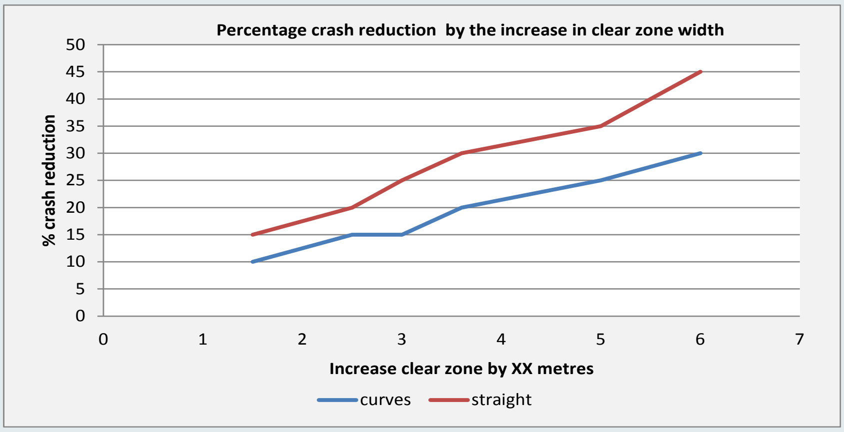
Treatment life

10+ years

References and guidelines

[3], [65], [97]

E7.2: Roadside hazards – open drains and steep slopes

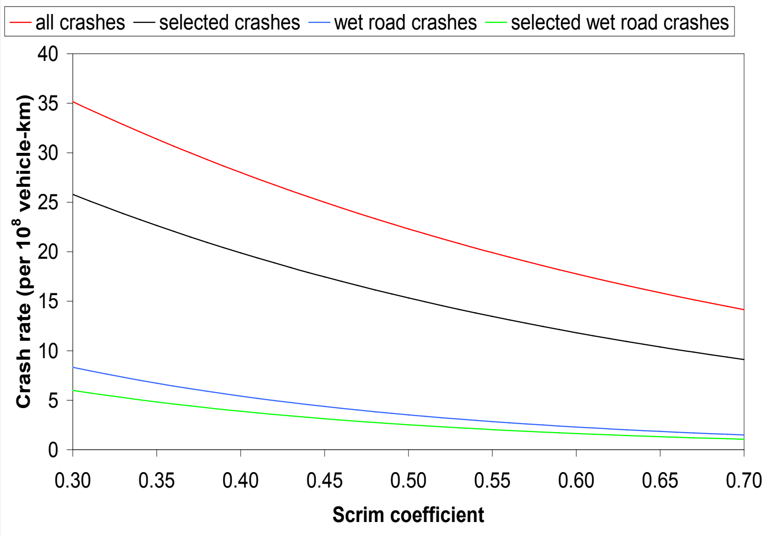
Description	Steep slopes (eg 1 in 4) and open drains which are commonly located within the clear zone on New Zealand roads are hazards to errant vehicles, particularly if located within the clear zone. 
Application	With regards to open drains, consideration should be given to piping or providing a side barrier to protect errant vehicles from the hazard. Steep slopes should be flattened to a traversable gradient or a side barrier installed to protect errant vehicles from the hazard
Issues	• It is not always possible to pipe drains, flatten slopes or put barriers around roadside hazards. Reducing vehicle speeds is an alternative solution. • High cost to reduce the hazard where drains are quite large • Headwalls/culvert crossings associated with vehicle crossings can be hazardous. Consider treatments to make these traversable.
Crash reduction	General removal of roadside hazards creates a 25–40% reduction in run-off-road injury crashes. [3] A percentage reduction in crashes by increasing the clear zone width is provided in the figure below. [65]  Providing a safety barrier to protect the hazard results in an 80% reduction in run-off-road injury crashes [97]
Other benefits	Nil
Cost	$-$$
Treatment life	5–10 years
References and guidelines	[3], [65], [97], [99]

Appendix F: Countermeasures – safety management measures

Measure	Number
Skid resistance and intervention levels	F1
Intersections	F2
Auxilary turn lanes	F2.1
Sight distance	F2.2
Priority control	F2.3
Signs and information	F3
Active signs (vehicle activated and variable speed)	F3.1
Variable message signs	F3.2
Vegetation maintenance and planting policies	F4

F1: Skid resistance and intervention levels

Routine resurfacing of rural roads generally reduces wet-weather crashes by 15% (initially) and increases dry weather crashes by 10% (initially) probably because of the increased speeds. The net effect is small (less than 5% initially) and diminishes over time.

Description	Skid resistance is a very complex issue that includes factors such as speed, water and/or detritus, micro texture, stone shape, etc, to name just a few. A wealth of research demonstrates the strong relationship between skid resistance levels and crash risk. These relationships support skid resistance policies such as NZTA T10/2010. [55]  Research undertaken in a number of countries consistently indicates that a disproportionately high number of crashes occur on road surfaces that have a low level of skid resistance (particularly below 0.4–0.5) and/or low surface texture (below 1mm in Sand Patch Texture Depth), particularly in higher-speed locations. The strongest skid resistance/crash relationships are typically found on two-lane undivided roads and at high demand areas such as curves and intersection approaches, which is why higher levels of skid resistance are recommended at these locations in the NZTA T10/2010 specification. However, these areas are also subjected to the highest levels of stress and consequently are often the hardest for which to maintain good skid resistance surfaces. Due to the large body of evidence supporting the effectiveness of measures to improve skid resistance and their net economic benefits, there can be high confidence in improving skid resistance through a variety of methods.
Application	The measurement of skid resistance can be undertaken via a variety of methods. Refer Austroads Guide to Asset Management Part 5F: Skid Resistance (2009). The NZTA undertakes annual surveys of the entire state highway network using the SCRIM machine. Some other New Zealand RCAs also undertake periodic SCRIM surveys. As a minimum the levels of skid resistance on the state highway network should be in accordance with the NZTA T10/2010 requirements. Particular attention should be given to the high-demand, high-risk areas and intersection approaches. The KiwiRAP Analysis Tool can also be used to identify the higher-risk areas, evaluating the run-off-road and head-on RPSs, in conjunction with the Curve Risk Rating levels developed by the T10 procedure and held within the RAMM database. Methods of improving skid resistance include: • resurfacing, particularly with a stone capable of providing a high level of skid resistance • slag surfacing • high Polished Stone Value surface treatments, eg epoxy-based products such as SafeGRIP • grooving, scabbling, waterblasting, although some of these provide short-term temporary relief only.

Issues	Consideration needs to be given to what the treatment life will be and what crash migration might occur when high skid resistance treatments are used at some sites but not adjacent to similar situations. The desire to equalise skid resistance provision versus demands across the network needs to be considered etc. Skid resistance will again deteriorate over time, especially in high demand, high volume sites
Crash reduction	Crash reductions will vary depending on the base state, level of improvement etc. Typically a 20% reduction in all crashes can be achieved by improving skid resistance levels by 0.1. Higher savings of about 35% can be expected in wet road crashes [137]
Cost	$-$$
Treatment life	3–10 years
References and guidelines	[55], [116], [137]

F2: Intersections

F2.1: Auxiiary turn lanes

Description	Right and left turn lanes on the main road approach are designed to allow traffic that is slowing to turn into a side road, to do so clear of through traffic from behind.
Application	Auxiliary turn lanes are installed where the volume of turning and through traffic creates a risk of rear end conflicts that result in rear end collisions or other secondary conflicts due to vehicles avoiding a vehicle that has slowed to turn or is stationary and waiting in order to turn. Guidance on the turning and through traffic volume ranges that should be considered for turn bays is found in the *High risk intersections guide.*  Right turn bay: SH33 Rotorua District (source : Google Pro licence 2010)
Issues	Rear end crashes are the main crash type prevented by auxiliary turn lanes. Rear end crashes rarely result in fatal and serious injury. Turning lanes have the potential to increase crossing and crossing-turning crashes, which are more severe. So it is important to ensure that minor crashes are not prevented at the expense of more severe crashes. At cross roads, right turn lanes increase the crossing distance and risk of crossing crashes. Where there is significant crossing traffic a roundabout should also be considered. Right turn lanes at t-junctions do not suffer from this problem. Typically designed left turn lanes increase the severe crash risk to vehicles turning right from the side road, as left turning vehicles using them obstruct visibility to through traffic, and the through traffic speeds are higher. This means that the volume criteria should be higher than for right turn lanes. Where provided, careful design of left turn lanes, islands and limit lines is necessary to preserve visibility from near the limit line. Turning lanes should be of appropriate length to the need. Hatching, continuity markings, and delineation should be used to ensure the through route is obvious and through traffic is not inadvertently trapped in a turning lane. Adding turning lanes to existing curves can disrupt the alignment, and the guidance provided by delineation. Curves may also have visibility issues that benefit from longer lane transition lengths (tapers). Auxiliary turning lanes should not be used in conjunction with passing lanes as drivers are tempted to use them to extend the passing opportunity.
Crash reduction	• 25–40% reduction in intersection crashes [3] • 30% reduction of casualty crashes with construction of right turn (rural) and/or left turn auxiliary lane [79] • 33% reduction in overall injury crashes [138]
Other benefits	• Improved traffic flow and increased intersection capacity
Cost	$$
Treatment life	10+ years
References and guidelines	[3], [79], [138]

F2.2: Sight distance

Description	Sight distance at an intersection is needed to allow traffic to identify safe gaps in the through traffic stream from near the limit line, and to allow through traffic to anticipate and accommodate traffic turning in or out of an intersection. (Further guidance on providing safe sight distance at intersections is contained in the *High-risk intersection guide.*  Sight distance restricted by vegetation looking from side road onto SH27
Application	The following low-cost solutions may be implemented to restore/improve the sight distance at intersections: [80], [83] • Remove/cut back the vegetation. • Relocate structures that impede sight distance (signs, safety barriers). • Flatten embankment or batter. • Bring forward the limit line, if this can be done safely.
Issues	Can be difficult to achieve in rural areas as a low-cost measure due to nature of the road. It is possible to have too much visibility as well as too little. If drivers approaching from a side road can see traffic on the main road from too far back, they may enter at a faster speed and judge the situation from too far back. They typically fail to notice motorcycles and cyclists. This is a known issue at roundabouts and crossroads.
Crash reduction	• 30% reduction in casualty crashes [80] • 28% reduction in total crashes [11]
Other benefits	Improved lighting
Cost	$
Treatment life	5–10 years
References and guidelines	[11], [80], [83]

F2.3: Priority control

Description	Priority control is either a stop or give way control at an intersection. Traffic signals, although a type of control, are not commonly used on rural roads and therefore are not discussed in the guide. 
Application	As stated in the Land Transport Rule: Traffic Control Devices, an intersection that has four or more approaching roadways must be controlled by: • stop or give way signs; or • roundabout (appendix D); or • traffic signal. Where there are three approaching roadways, then discretion on their use with regards to the function and traffic volumes of the road is considered by the RCA.
Issues	• The use of a stop sign where not warranted (ie where there is sufficient sight distance). A stop sign should not be used to reinforce a road hierarchy or as a routine response to an actual or perceived problem as this can decrease the effectiveness of the control type. • Further analysis on safety performance will be completed as part of the *High-risk intersection guide* (currently under development).
Crash reduction	• 15% reduction in crashes for give way signs [84] • 35% reduction in crashes for two-way stop signs at a four-legged cross intersection [84] • 20% reduction in crashes for a one-way stop sign at a T-intersection [84]
Other benefits	Improved traffic flow (may also be a cost due to increased delays to major road flow)
Cost	$
Treatment life	5–10 years
References and guidelines	[84]

F3: Signs and information

F3.1: Active signs (vehicle activated and variable speed)

Description	An active sign is a warning sign that has an electronic display component which becomes active when the activity or hazard described by the sign (eg children on the road, out of context curves, slow down, queues ahead) is likely to be occurring on or close to the road. They can also include: • vehicle-activated signs • speed-activated warning signs (SAWS) • variable speed signs. 
Application	Should be restricted to sites where the RCA considers that none of the standard warning signs will provide adequate warning to approaching drivers.
Issues	• Ownership and responsibility – eg is a 'cattle ahead' electronic warning sign or flashing light the farmer's responsibility to operate and maintain or the RCA's responsibility? • Legal liability in event of power or equipment failure • Vandalism, especially in rural areas • Power source (solar-powered signs are available) • Daylight saving time adjustment • Enforcement
Crash reduction	• 35% reduction in all crashes [44] • 30–35% reduction in crashes at rural curves and intersections [90]
Other benefits	• Reduced traffic speed with speed activated and dynamic speed signs
Cost	$
Treatment life	5–10 years
References and guidelines	[44], [88], [89], [90]

F3.2: Variable message signs

Description	A variable message sign (VMS) is an electronic sign in which the message can be changed in content, form, shape, layout and/or colour. Such signs may be illuminated or otherwise. They can be permanently located or portable.  (Source: the NZTA's *Traffic control devices manual* – General requirements for traffic signs.
Application	A VMS can be used to: • actively manage traffic flows • complement changeable message signs (CMS) to enhance travel information measures • warn road users of unusual conditions that may affect traffic operations on the roading network • provide real-time travel information to road users • complement the fixed warning signs for temporary traffic control
Issues	Vandalism Power supply can be an issue in rural areas
Crash reduction	The use of VMS can be related to a range of issues along a route such as traffic control, traffic diversion and hazards. Therefore it is difficult to provide a crash reduction figure.
Other benefits	Can provide real-time information and therefore reduce travel times and driver frustration
Cost	$-$$
Treatment life	10 years
References and guidelines	[2], [46], [139]

F4: Vegetation maintenance and planting policies

Description

Vegetation maintenance can include the trimming or removal of vegetation as required, maintaining sight distances and removing hazards from clear zones. Clear guidance should be provided in planting policies to ensure that hazards are not created.

Application

RCAs should develop planning policies to maintain a clear zone. Reference can also be made to using shrubs and plants (those that are frangible, ie with a trunk that is generally less than 100mm wide, which would also be safer and reduce severity of injury to motorcyclists) to create visual vertical narrowing effects to reduce operating speeds where it would not compromise safety and sight distances.

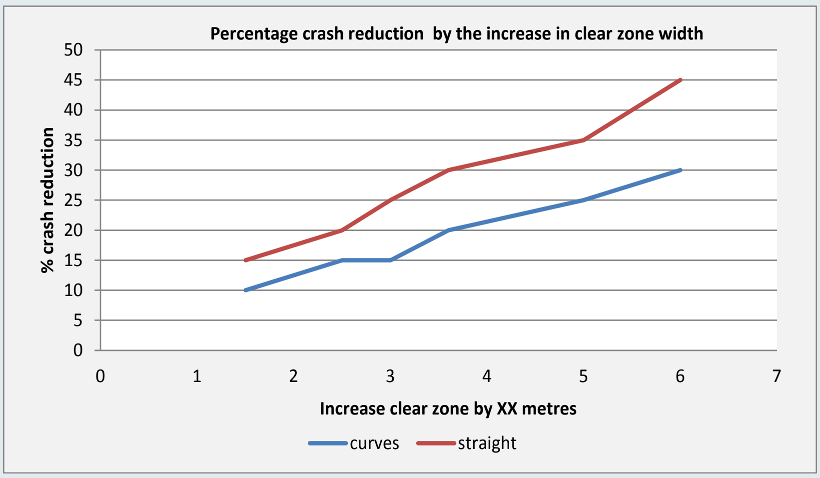
Issues

- Effects on the environment and community values need to be considered before removing vegetation
- The roadside needs to be left in a safe condition following vegetation maintenance (eg no tree stumps should be left that may be hazards)
- Regrowth of vegetation and soil erosion from removal of vegetation need to be considered
- Overgrown vegetation can obscure signs and markings and create maintenance issues
- Plants may interfere with sight distances at intersections and on road curves and low planting in these areas should be utilised.
- Overhanging tree branches can interfere with truck and bus traffic and may cause these vehicles to swerve into adjacent lanes to avoid damage to the vehicle or load

Crash reduction

'Generally, the removal of a fixed object like a tree results in a 50% reduction in fatality crashes and a 25–35% reduction in non-fatality crashes at that location. However, these values depend on the distance of the object from the traffic; the further away the fixed object is located, the less likely is a crash which will result in an errant vehicle hitting the object, hence there is a lesser benefit from removing it.' [61]

General reductions in crashes are shown in the chart below [65]



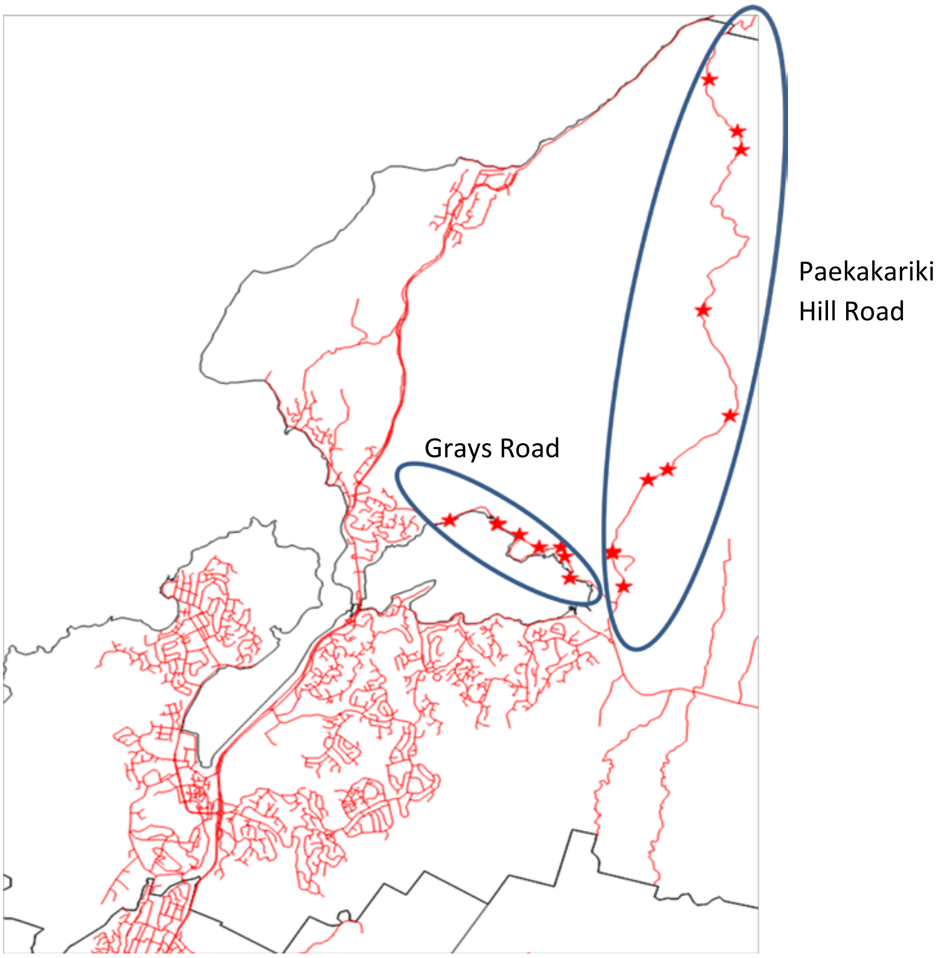
Other benefits	• Visually appealing landscape values • Manage stormwater runoff • Provide traffic calming • Promote biodiversity • Improve air quality
Cost	$
Treatment life	1–10 years
References and guidelines)	[61], [65]

Appendix G: Worked examples

Using CAS (state highway or local roads): local road examples

Porirua City

Porirua City has undertaken a crash study investigating fatal and serious injury crashes on their rural roads. The study has identified two potential high-risk rural roads: Grays Road and Paekakariki Hill Road. This example discusses Grays Road.



Grays Road is approximately 5.5km long with a small section of 50km/h at the start. On the remaining 4.8km of 80km/h rural road eight high-severity crashes have occurred over the five-year period 2004 to 2009. This rural section is relatively flat, but follows a winding alignment and carries approximately 5800 vehicles per day.

Personal Risk = 8 high-severity crashes / (4.8km x 5800 AADT x 5 years x 365 days / 10^8)

= 8 / 0.51

= 15.7 high-severity crashes per 100 million vehicle kilometres of travel

This route is a **high personal risk** (using figure 4-2), and has a minimum of 3 fatal or serious crashes; therefore the route is defined as a high-risk rural road.

Collective Risk = 8 high-severity crashes / 4.8km / 5 years

= 0.33 high-severity crashes / km / year

This route is a **high collective risk** (using figure 4-1), and therefore defined as a high-risk rural road.

FIGURE G-1 Treatment Philosophy

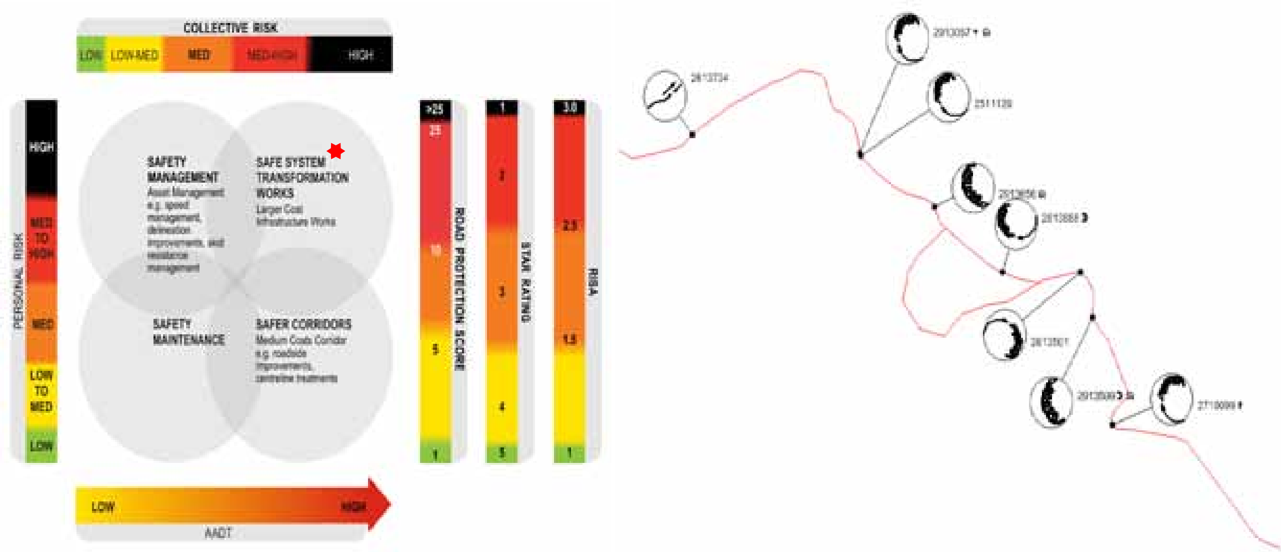


Figure G1 shows that because this route is both high collective risk and high personal risk transformational works such as major realignments may be appropriate.

In addition, the crash reduction study identified Grays Road as a route within the district that has an overrepresentation of crashes, particularly lost control and head-on type crashes, crashes in the wet and a number of hit objects crashes.

Because the route is not of high strategic planning importance, higher cost infrastructure works were not supported, and lower cost approaches considered.

Hastings District Council

In this example the Hastings District Council is interested in identifying potential high-risk rural routes on their network. The process begins with plotting the high-severity crashes on rural roads in CAS, as shown in figure G-2. A review of the data suggests a number of possible corridors that may be worthy of further investigation, as illustrated in figure G-3. Although the local knowledge is needed to support the selection of possible corridors, we have selected Route A for this example.

FIGURE G-2 High-severity crashes on a network

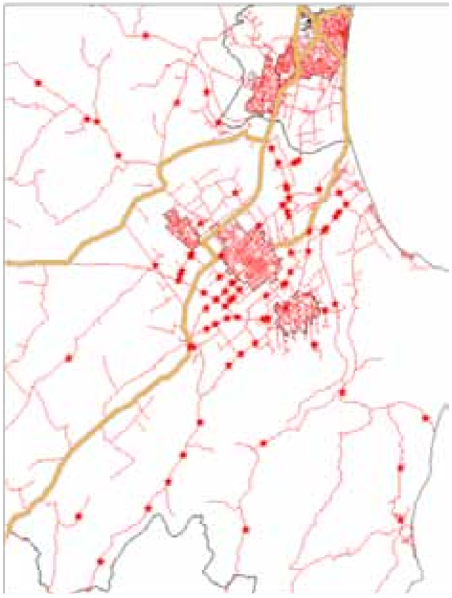
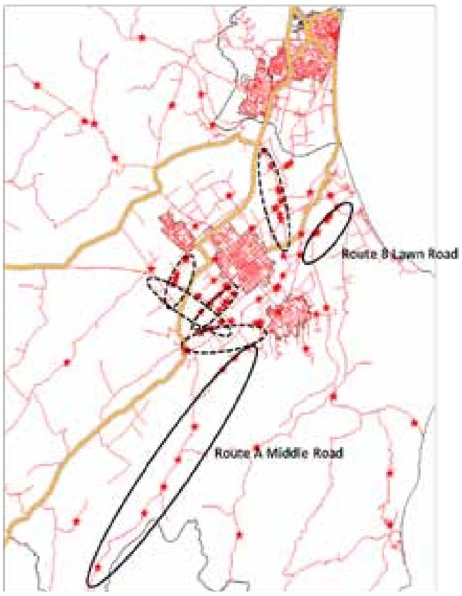


FIGURE G-3 Possible route of interest



Route A

Route A is a section of Middle Road 24km long and carrying around 500 vehicles per day. There have been eight high-severity crashes in five years. Using the calculations in sections 4.3.3, we obtained the following results for risk:

Personal Risk = 8 high-severity crashes / ((25km x 500 AADT x 5 years x 365 days) / 10^8)

= 8 / 0.22

= 36 high-severity crashes per 100 million vehicle kilometres of travel

This is a **high personal risk** as per figure 4-2 and is deemed to be a high-risk rural road using the definitions described in section 4.1.

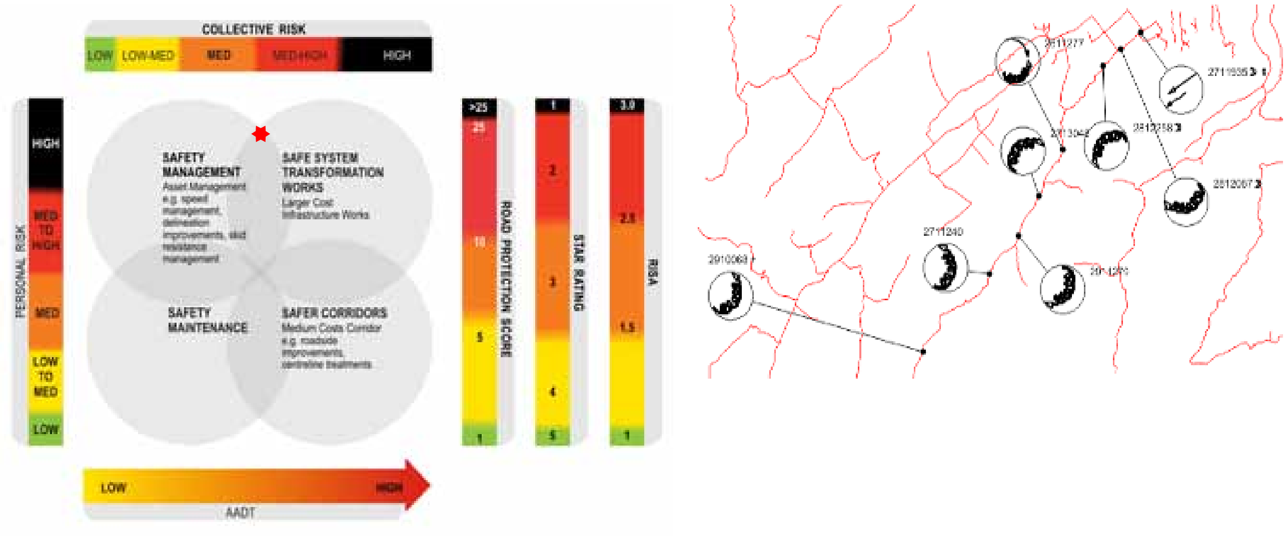
Collective Risk = 8 high-severity crashes / 25km / 5 years

= 0.06 high-severity crashes per km per year

This is a **medium collective risk** as per figure 4-1, but as it has a high personal risk this is still deemed to be a high-risk rural road.

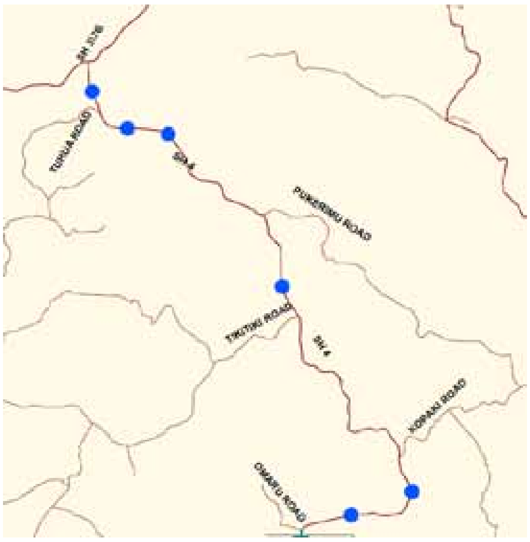
When mapping high personal and medium collective risk onto the treatment philosophy strategy chart (figure G4) for Route A, the 'red star' sits in the middle of Safety Management and Safe System Transformation Works; however, the most effective treatment for this route is expected to revolve around Safety Management as it has a low number of crashes and low traffic volume. For example, for a site where there has been an identified issue with loss of control on bend type crashes, consideration could be given to providing higher levels of delineation (a Safer Corridors treatment), including a consistent application of curve signage along this route.

FIGURE G-4 Safety strategy for Middle Road



Using CAS and RAMM (state highway or local roads): SH4 from SH3 to Omaru Road

State highway example – SH4 from SH3 to Omaru Road



Using a combination of CAS data, high-severity crashes and RAMM, a safety engineer sets out to find 20km lengths of network on which there have been recorded 3 or more high-severity crashes (this is the minimum number of crashes that would determine whether a route could be a high-risk rural route.

A section of SH4 (RS 0/0 to RS 15/3000) has had 6 high-severity crashes in the past five years and should be investigated further. The highway carries an average of 2190 vehicles per day. Using the calculations in sections 4.3.3, we obtained the following results for risk:

Personal Risk = 6 high-severity crashes / (20km x 2190 AADT x 5 years x 365 days) / 10^8

= 6/ 0.8

= 7.5 high-severity crashes per 100 million vehicle kilometres of travel

This route is a **medium-high personal risk** (using figure 4-2).

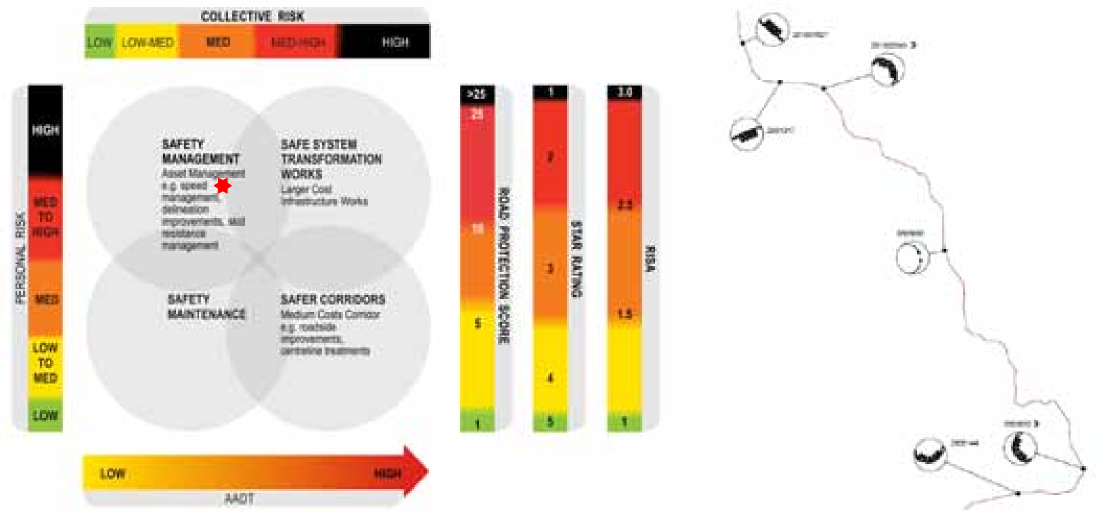
Collective Risk = 6 high-severity crashes / 20km / 5 years

= 0.06 high-severity crashes per km per year

This is a **medium collective risk** (using figure 4-1) and is therefore not defined as a high-risk rural road as described in section 4.1 (however the personal risk still constitutes thi high-risk rural road).

Using the treatment strategy diagram, we see that the medium-high personal risk and medium collective risk puts us in the lower part of the Safety Management quadrant.

FIGURE G-5 Safety strategy for SH4



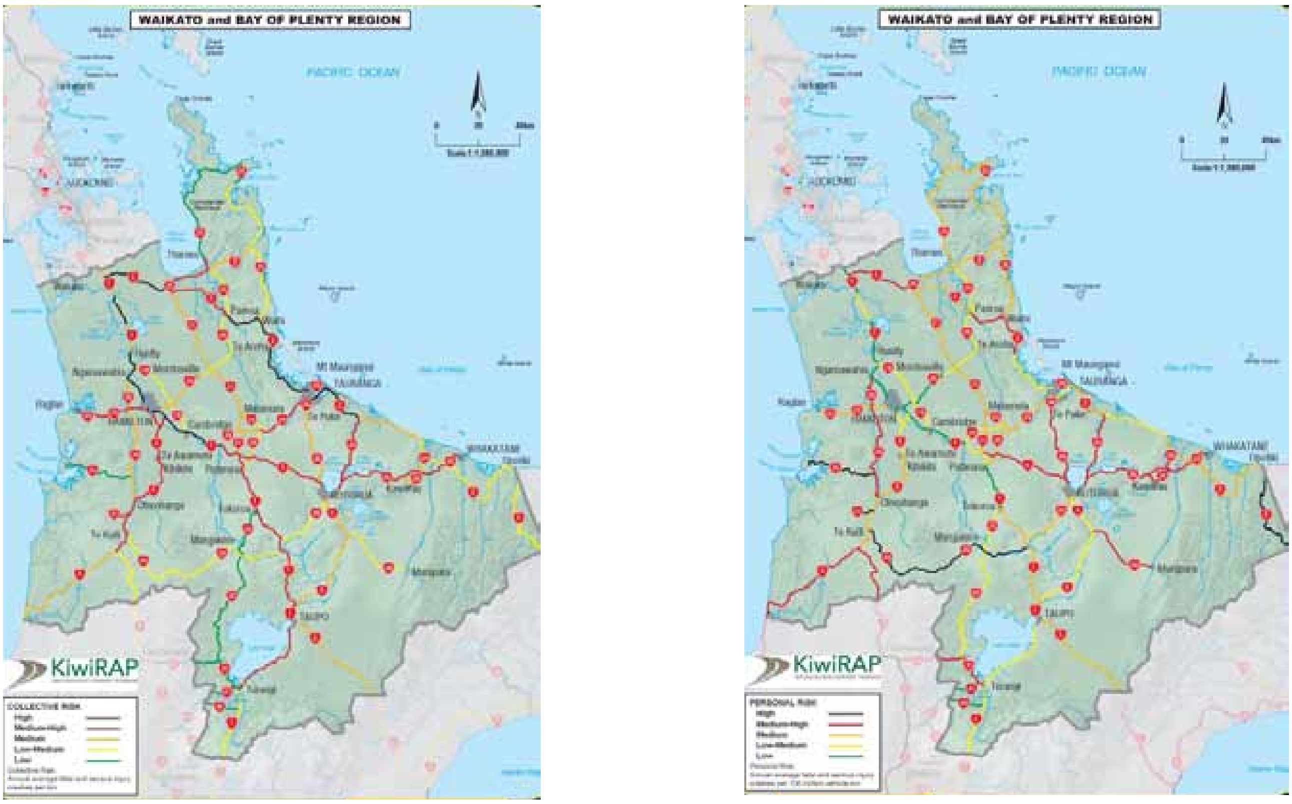
When analysing the high-severity crashes further we see that there are 67% loss of control on bend crashes through the route. When using all crash data to determine underlying issues (as discussed in section 5) we see that 74% are loss of control on bend crashes and that 45% occurred in wet road conditions.

Using the treatment strategy philosophy and then analysing the underlying issues for the route suggests there is scope for delineation improvements and skid resistance treatments.

Using KiwiRAP Crash Risk Maps (State Highway only): SH2: Katikati to Tauranga

The 2008 KiwiRAP crash risk mapping (based on 2002 to 2006 crash data) identified 32 Black Routes, sections of state highway with the highest collective crash risk. One of these was a 27km section of State Highway 2 from Tauranga to Katikati, which ranked 26th worst in New Zealand.

FIGURE G-6: KiwiRAP crash risk maps (2002 to 2006 data)



We further clarified and updated the crash data (using CAS) and determined that, over the period 2005 to 2009 inclusive, there have been 30 high-severity crashes over the 27km route which carried around 11,500 vehicles per day in 2007. Using the calculations in sections 4.3.3, we obtained the following results for risk:

Personal Risk = 30 high-severity crashes / ((27km x 11,500 x 5 x 365) / 10^8)

= 30 / 5.66

= 5.29 high-severity crashes per 100 million vehicle kilometres of travel

This route is a **medium personal risk** (using figure 4-2) when using only this factor and the definitions described in section 4.1. This compares to a lower medium published personal risk (as per figure G-6 above) based on the 2002-2006 data. This route does not constitute a high-risk rural road.

Collective Risk = 30 high-severity crashes / 27km / 5 years

= 0.22 high-severity crashes per km per year

This is a **high collective risk** (using figure G-6), and therefore the route is a high-risk rural road as described in section 4.1 (even though personal risk does not constitute a high-risk rural road). This high collective risk is the same as that published in figure G-6.

Using the treatment philosophy strategy (figure 4-6) shows that this section of highway lies on the boundary between Safe Systems Transformation Works and Safer Corridors treatments (see figure G-7 red star). However, using the KiwiRAP star rating of 2.8 (obtained from the KAT tool – figure G-8) would suggest a greater focus on the road infrastructure improvements (see figure G-7 green star).

FIGURE G-7 Treatment philosophy

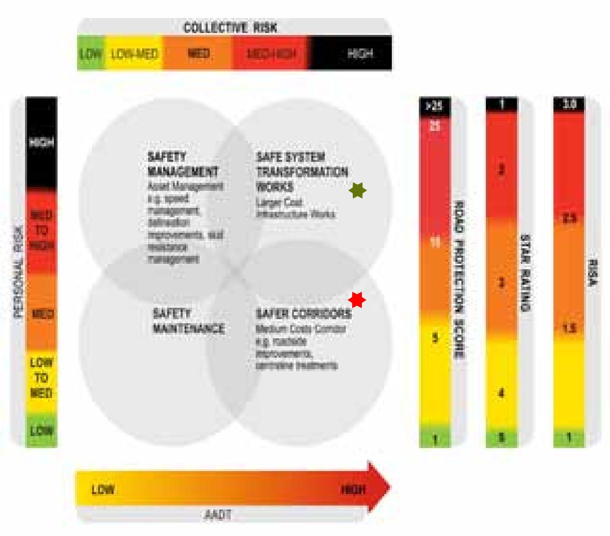
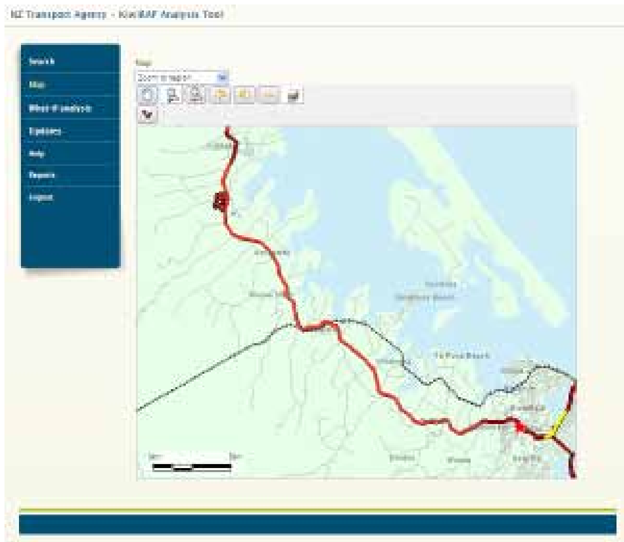
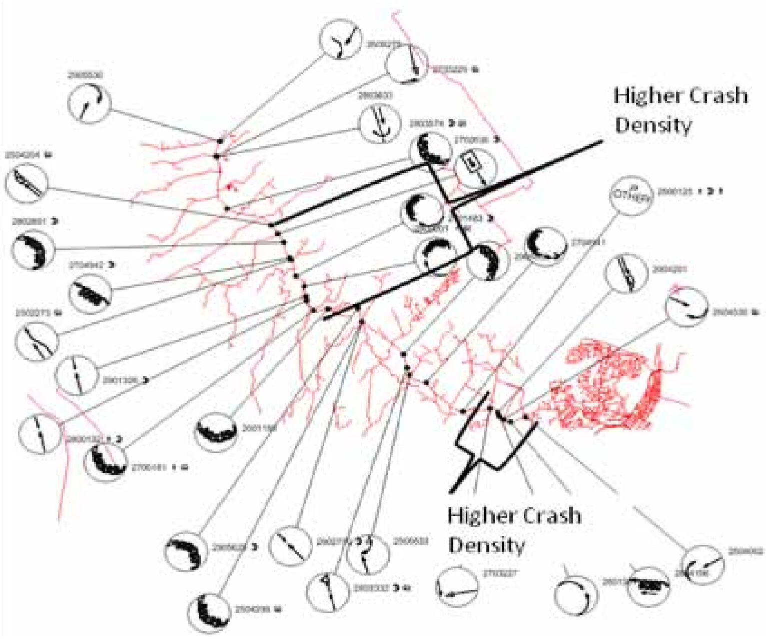


FIGURE G-8 KAT search map



Plotting the high-severity crashes in CAS (figure G-9) we find the crashes are distributed along the route, as opposed to being clustered, suggesting a corridor approach may be warranted. There is however a higher density of crashes over the 9km section beginning around RS 116/10. While treating the whole corridor may be worth considering, given there is a further high-density section to the south, focusing attention on the section around RS 116/10 may be worthwhile bearing in mind the discussion regarding shorter sections within KiwiRAP risk mapping in section 4.4.4.

FIGURE G-9 CAS-reported high-severity crashes (2005 to 2009 inclusive)



Investigating the entire route further in the KiwiRAP Analysis Tool (KAT) we can explore in more detail the engineering attributes that contribute to the overall star rating of 2.8. The unfactored run-off-road RPS is 7.6, while the unfactored head-on RPS is 12.5. These are then factored by a ratio of 65% to 35% for run-off-road to head-on, and the intersection score is added to give an overall RPS score. The ratio is supported by the fact that 9 of the 30 high-severity crashes (30%) involved crossing the centreline. The high head-on RPS indicates that a treatment that provides a central median barrier may be worth considering.

Even though this example shows that we have an actual number of 30 high-severity crashes over 5 years we can also determine what the predicted crash rate is by referring to Appendix C. Using figure C2 within this appendix, the calcuated star rating of 2.8 would show a predicted injury crash rate of 20 injury crashes per 100 million vkt.

To convert to equivalent potential reported injury crashes per year:

$$= \frac{\text{injury crash rate * AADT * length (km) * 365(days of the year)}}{10^8}$$

$$= \frac{20 * 11\,500 * 27 * 365}{100\,000\,000}$$

= 22.6 injury crashes per year

Therefore the potential high-severity crashes

= 22.6 * 30%[16]

= 6.78 high-severity crashes per year or 3.6 crashes in 5 years.

When comparing to the actual crash numbers of 30 high-severity crashes over a five yer period or 6 crashes per year we get a relatively good correlation.

A further investigation in KAT 'what if' analysis suggests that dividing this carriageway with a median barrier would see the star rating increase from 2.8 to 3.3 which equates to a 30% reduction in the crash rate.

As per the discussion in appendix C, it is difficult to use the improvements in the KAT 'what if' analysis to determine the number of high-severity crashes using the Safe System treatments as the injury reduction figure could be conservative compared to what the actual reduction could be.

16 High-severity crashes (fatal and serious injuries) typically make up approximately 30% of the reported injury crashes.

Using KiwiRAP Star Rating Maps and KAT (State Highways Only): SH7 Reefton to Lewis Pass

As a result of using the definitions of a high-risk rural road provided in section 1.2 and 4.1 we find a 2 star road (SH 7 - between Reefton and Lewis Pass in the South island) using the KiwiRAP star rating maps shown in figure G-10 to investigate further; however to make sure it meets all the requirements of defining it as a high-risk rural road, we would need to show the likely crash numbers of at least 3 high-severity crashes in five years or 5 high-severity crashes in 10 years.

Using KAT we further define a 15km length of SH7 (RP 7/131/0 – 131/15.00) within this route. The KAT outputs show the section of road has a calculated star rating of 2.77 (KAT - figure G-10). The AADT is 1170 vpd.

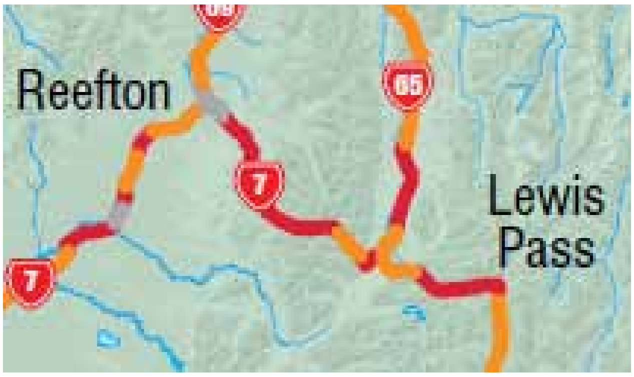
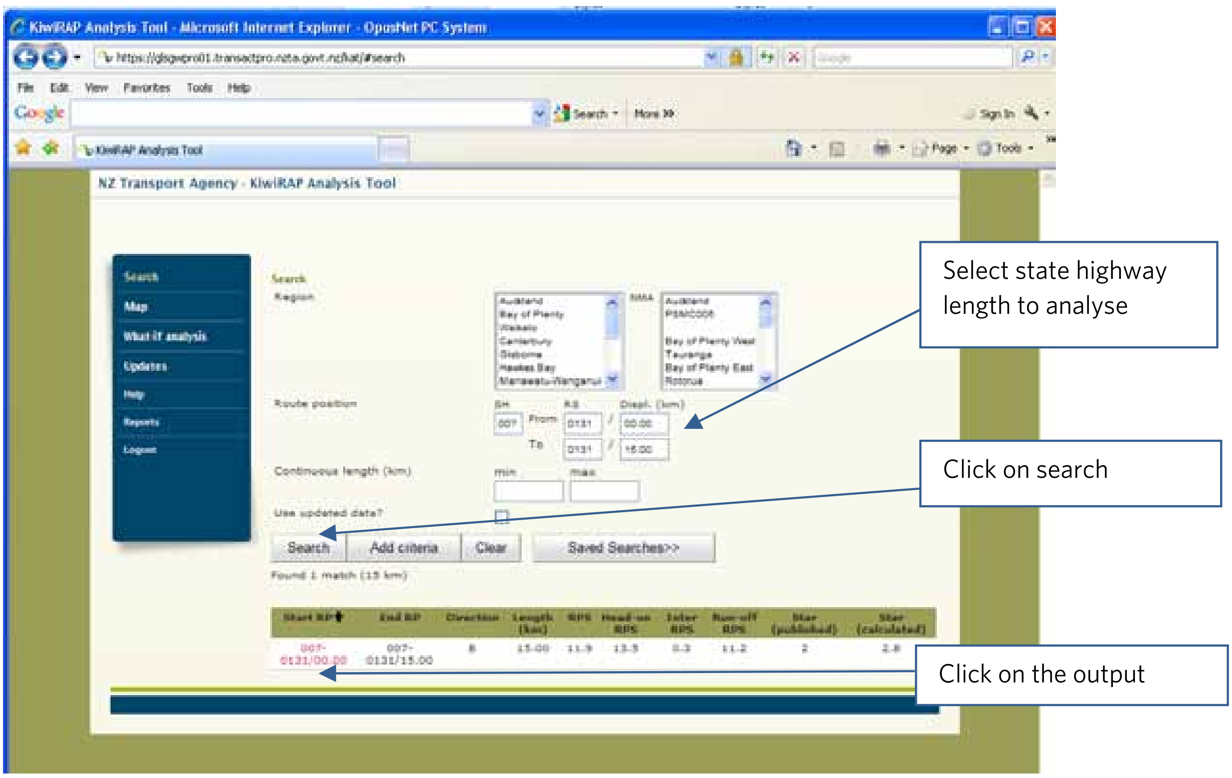
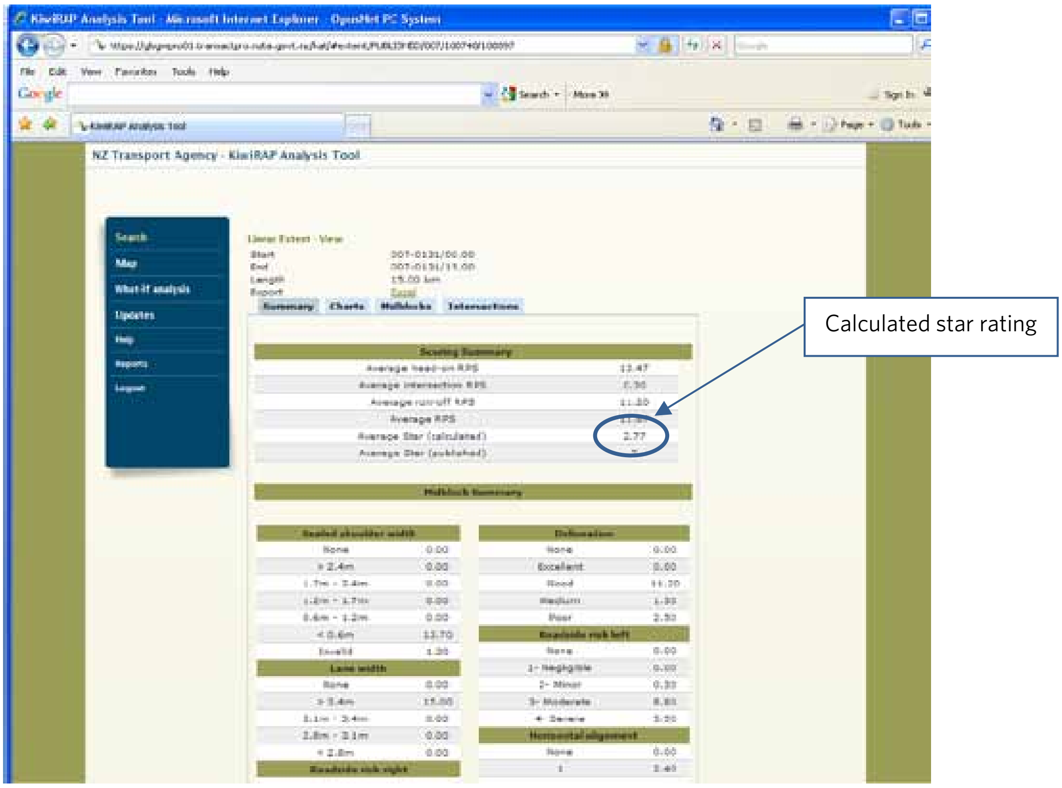


FIGURE G-10 KiwiRAP star rating maps





Using appendix C, figure C2 and the calcuated star rating of 2.77 (round to 2.8), the predicted injury rate is 20 inury crashes per 100 million vkt. To determine the injury crash rate per year we calculate:

$$= \frac{\text{injury crash rate * AADT * length (km) * 365 (days of the year)}}{10^8}$$

$$= \frac{20 * 1\,170 * 15 * 365}{100\,000\,000}$$

= 1.28 predicted injury crashes per year

Therefore the potential high-severity crashes

= 1.28 * 30%[17]

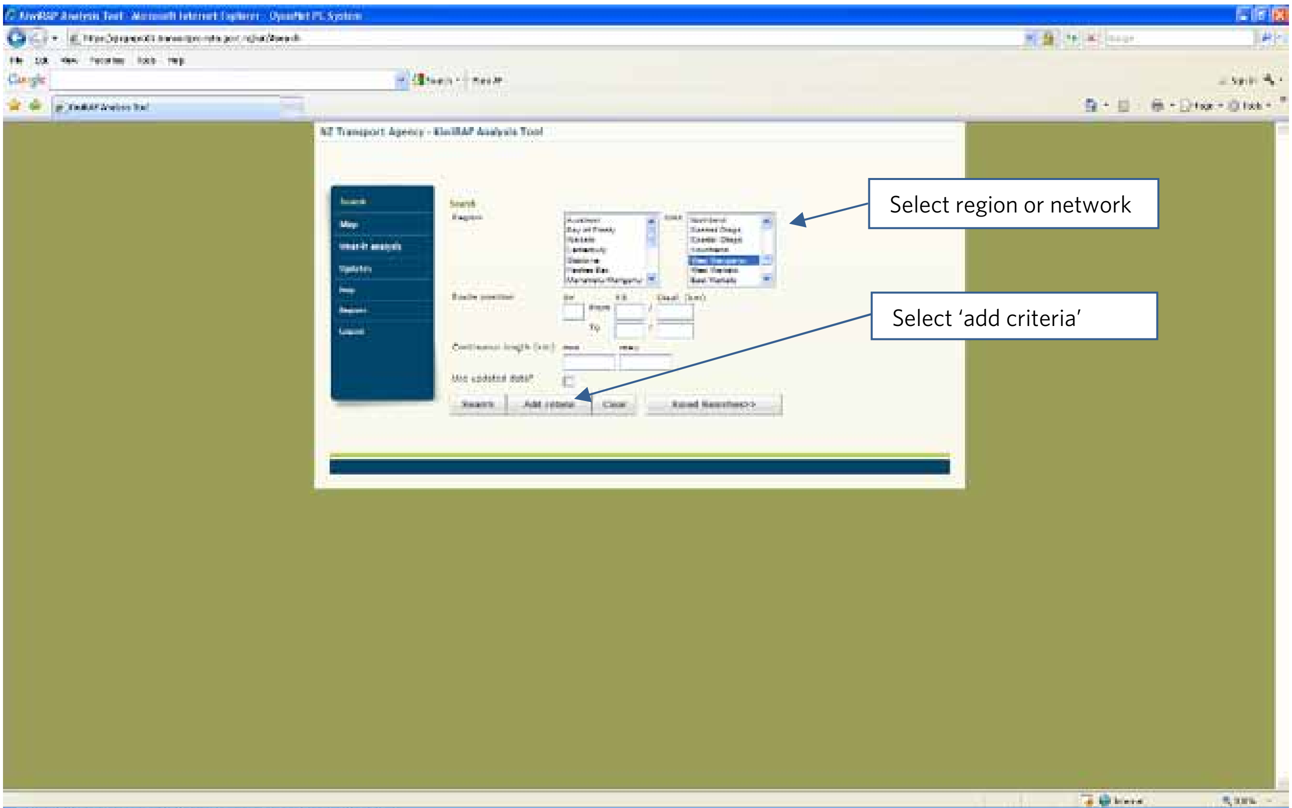
= 0.38 high-severity crashes per year or 1.9 high-severity crashes in 5 years.

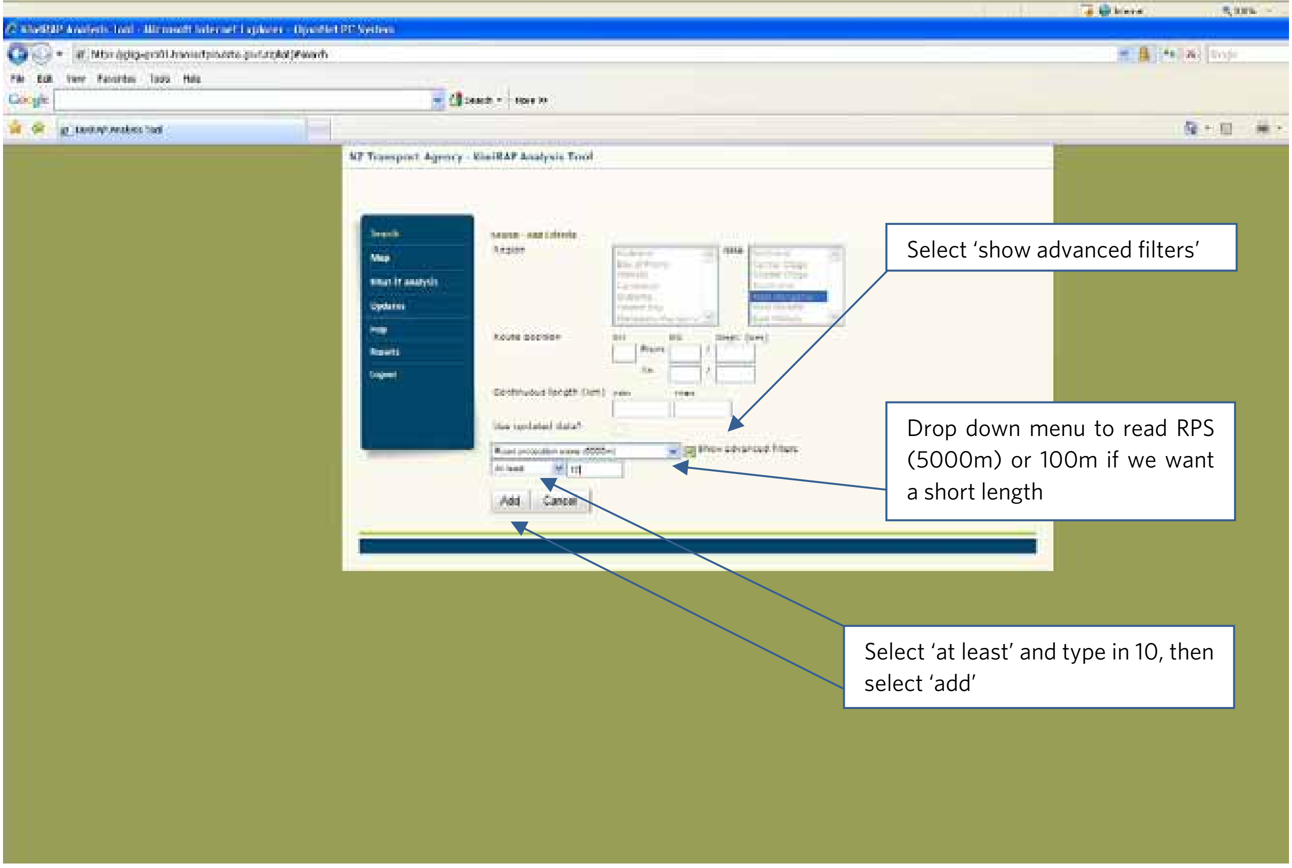
What this shows us is that even though we have defined a high-risk rural road (using definitions in sections 1.2 and 4.1 of the roads that have a star rating of 1 or 2), with 1.9 potential high-severity crashes in 5 years we do not have the minimum number of potential high-severity crashes (3 or more in 5 years or 5 or more in 10 years) to justify it being defined as high-risk rural road.

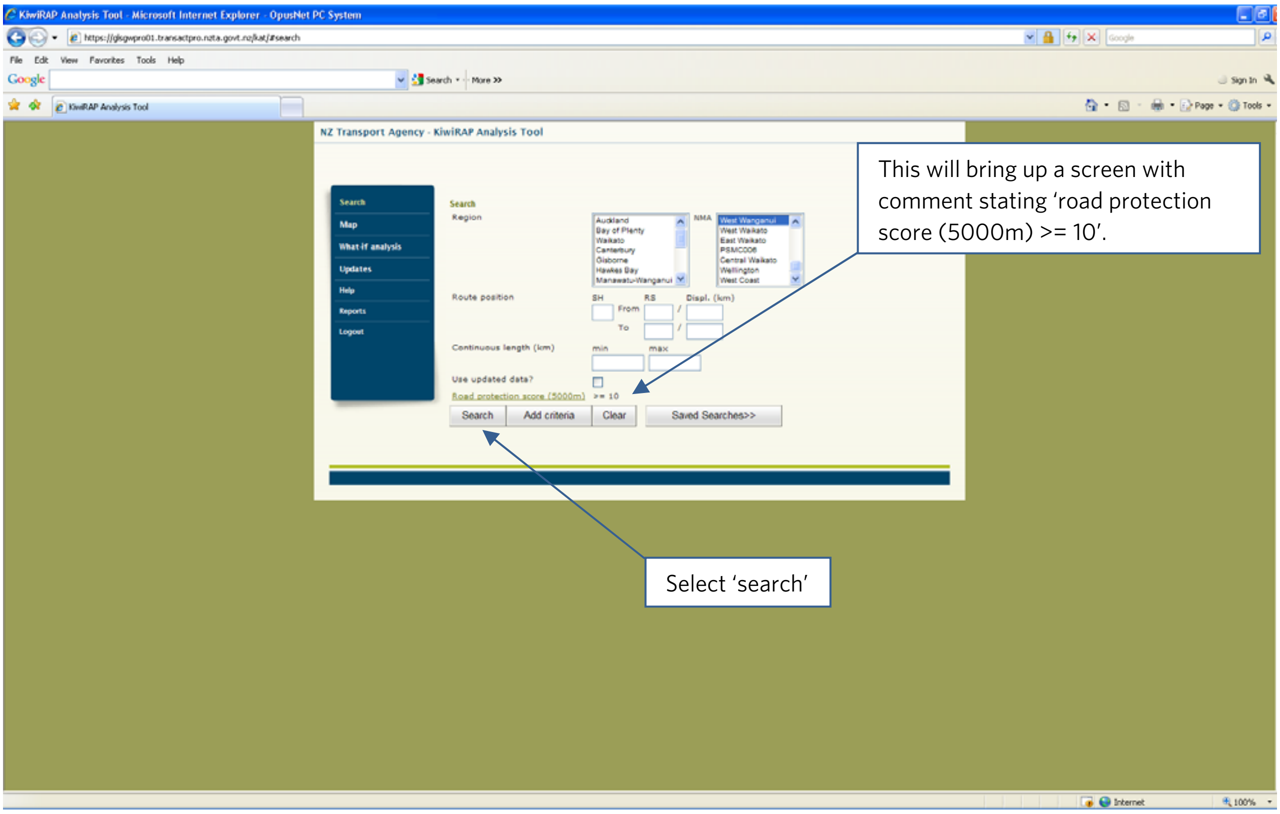
17 High-severity crashes (fatal and serious injuries) typically make up approximately 30% of the reported injury crashes.

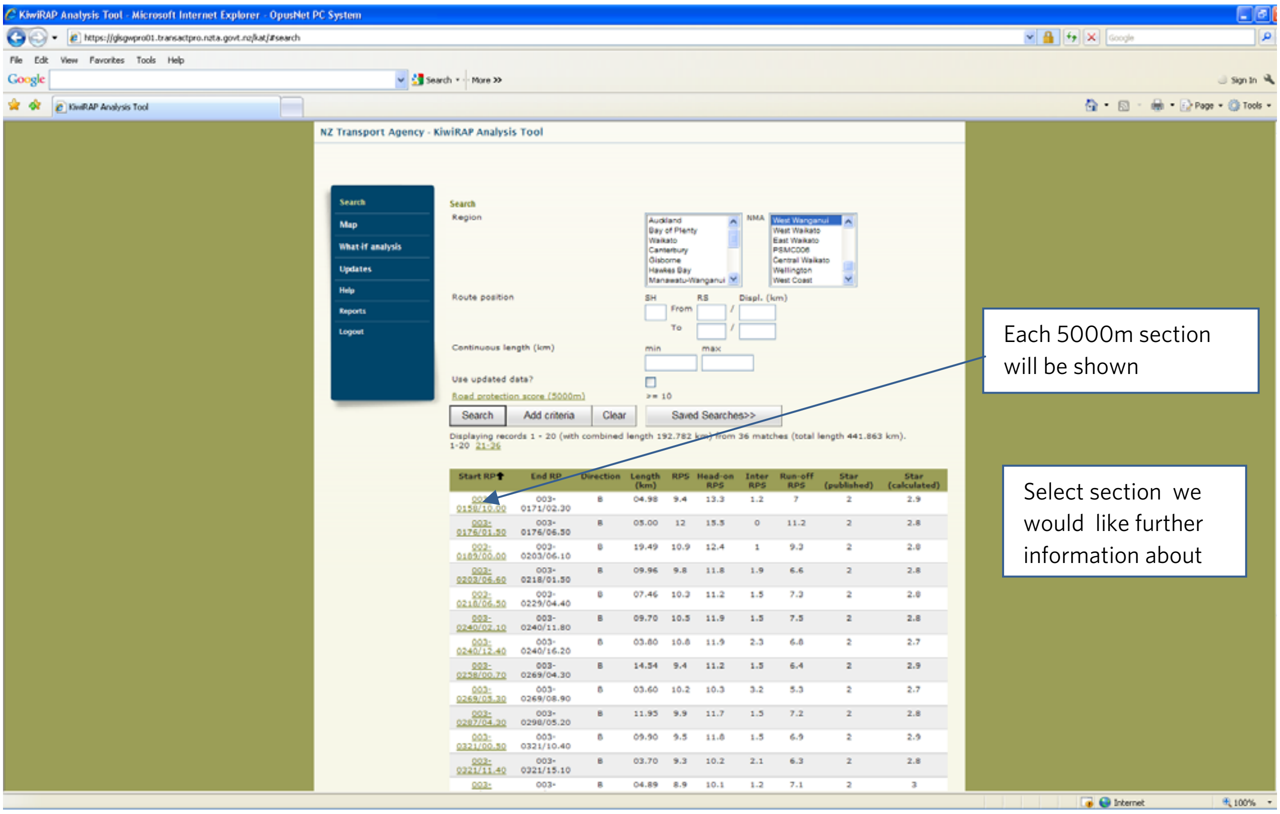
Using KAT (State Highways only)

The following process shows the use of KAT to determine 5km length of high-risk rural road within networks.

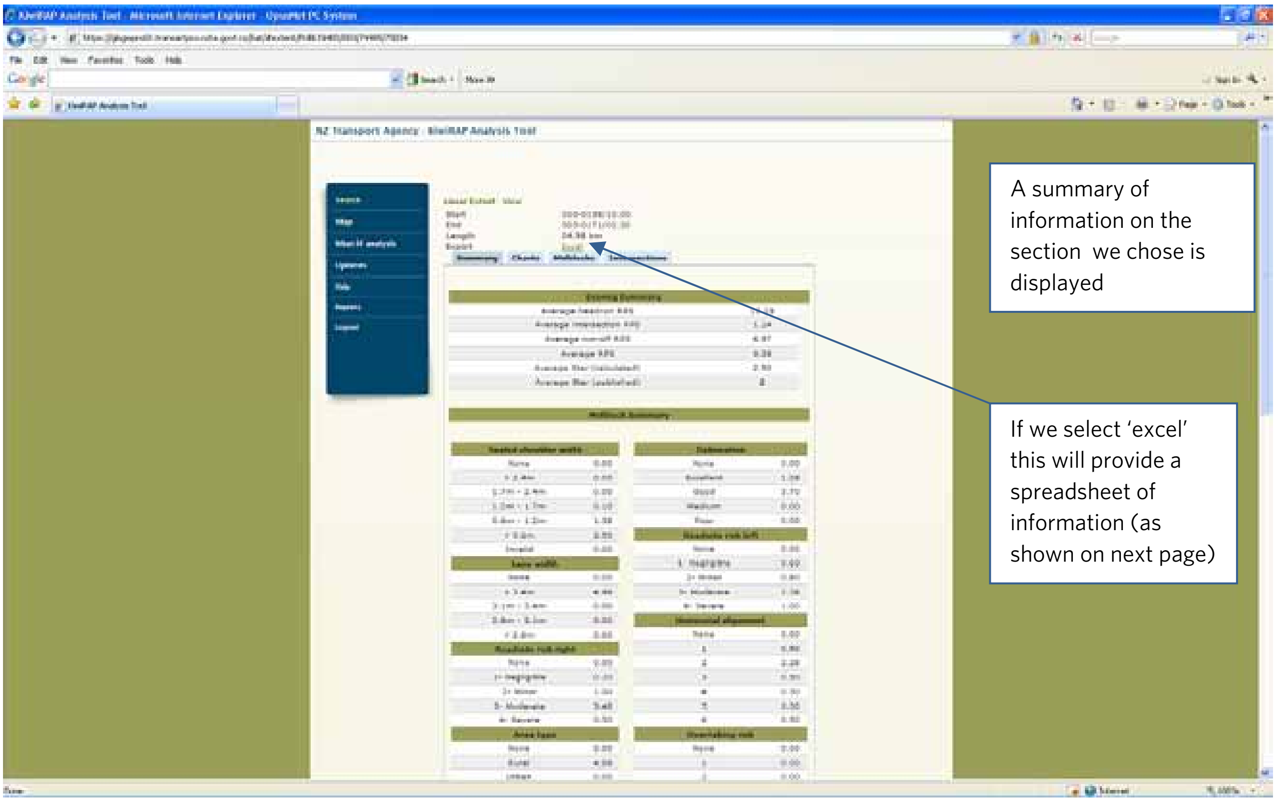






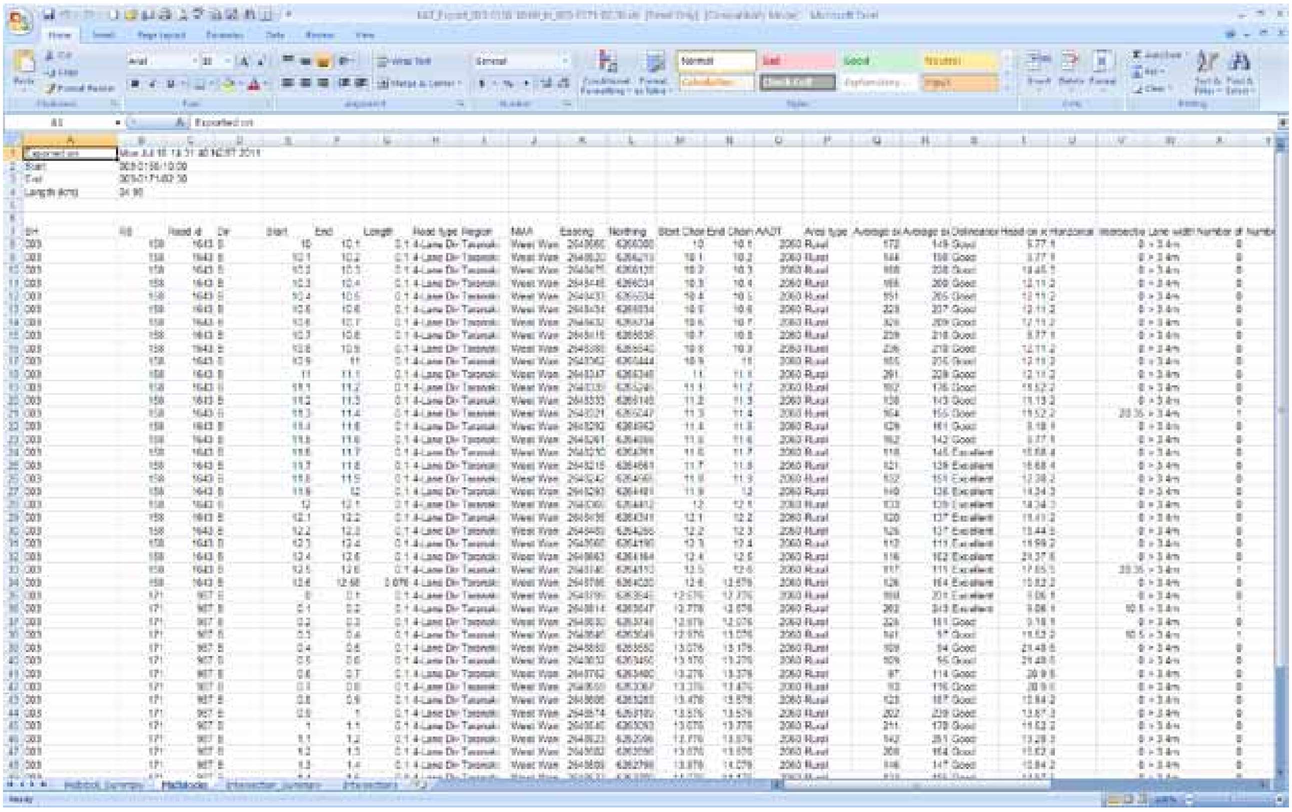


Note: the programme does not currently allow you to select the whole network to gather further information



The Excel output looks like the following.

This information can then be exported and used for sorting of information and mapping purposes.



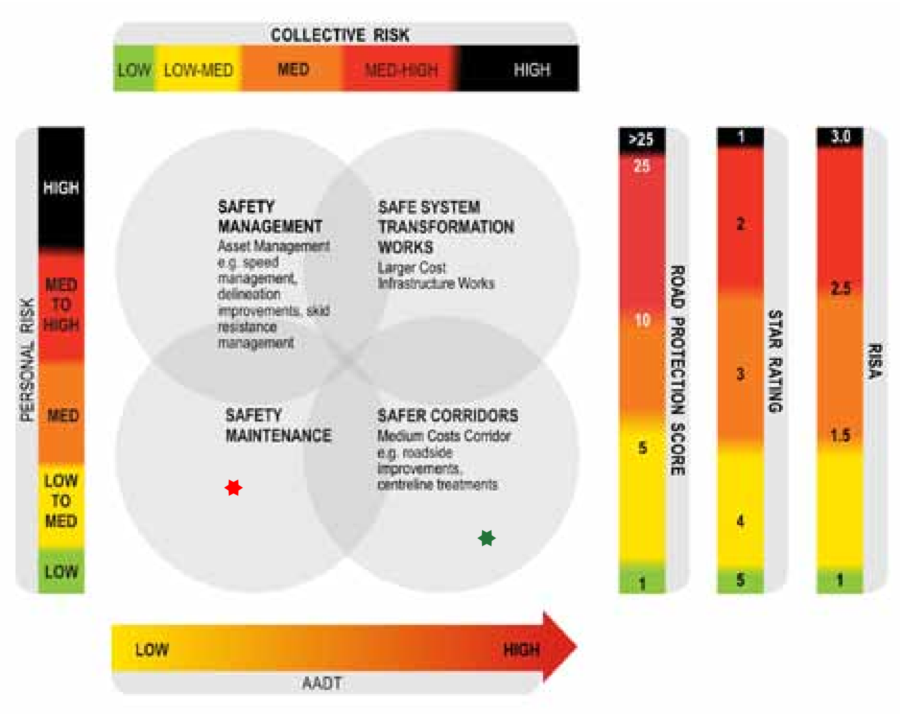
Using RISA (Local Roads only)

A road where a RISA audit has been undertaken can be used to determine the appropriate treatment strategy. Using an example for a study completed on a local road network the following results were given to a number of local roads for both collective and personal risk.

Road Name	Personal Risk (unfactored risk)	AADT
Road A	1.6	144
Road B	1.1	4600
Road C	1.4	520
Road D	1.2	3200
Road E	1.3	1130
Road F	1.3	6000

Using the treatment philosophy diagram (figure G-11) we can plot the personal risk on the y-axis and use AADT for the x-axis value to determine the appropriate treatment strategy. For example we used Road C with a personal risk of 1.4 and AADT of 520 (red star) we could see that it would likely be a safety maintenance type treatment strategy due to the lower volumes[18], if we compare with Road F, with a personal risk of 1.3 and AADT of 6000 this would likely fall into the safer corridors treatment strategy (green star) .

FIGURE G-11 Treatment philosophy strategy



18 Note that a 'low'and a 'high' value for AADT can be determined by the RCA and will be based on their range of network traffic volumes

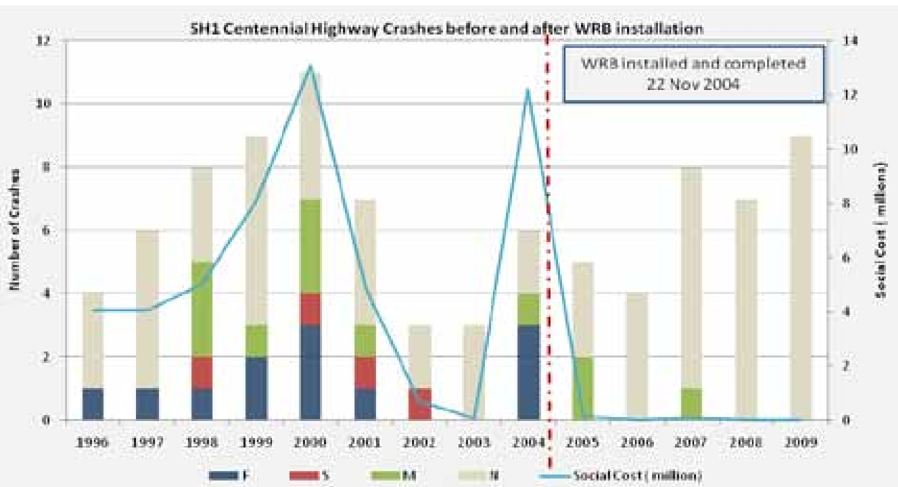
Current project case studies

Centennial Highway[19]

This paper reports on the performance of a wire rope barrier (WRB) on a narrow median installation on Centennial Highway, New Zealand. Since the speed limit was reduced from 100km/h to 80km/h and the median WRB was installed, no fatalities or serious injuries have occurred. The median barrier was introduced in two stages (front section 700m) and has been very successful in reducing road trauma.

Prior to stage one the average annual social cost of crashes on Centennial Highway was $5,796,889. This has since reduced to an average social cost of $65,400 per year. Surveillance of the Centennial Highway median WRB showed that vehicles generally sustained relatively little damage when they struck the barrier and were often observed to drive away after the impact. Drivers also tended to travel more centrally within their lane with the barrier in place. While the narrow median on Centennial Highway has resulted in an increase in maintenance costs due to impacts on the WRB, this cost has been significantly offset by reductions in trauma costs.

The use of a narrow median WRB has proven to significantly reduce crash severity and is considered an appropriate solution when retrofitting existing roads, particularly in constrained environments. However, it is recommended that wider medians could be adopted wherever possible to minimise the associated maintenance costs. Ideally, the median width should provide at least sufficient space to fully accommodate the design deflection of the selected barrier system; however this is not crucial given it is recognised that actual risk of a collision with an opposing vehicle is quite low even with a narrower median



19 'Evaluation of Narrow Median Wire Rope Barrier Installation on Centennial Highway, New Zealand' By F. Marsh and M. Pilgrim (2010)

Rangiriri[20]

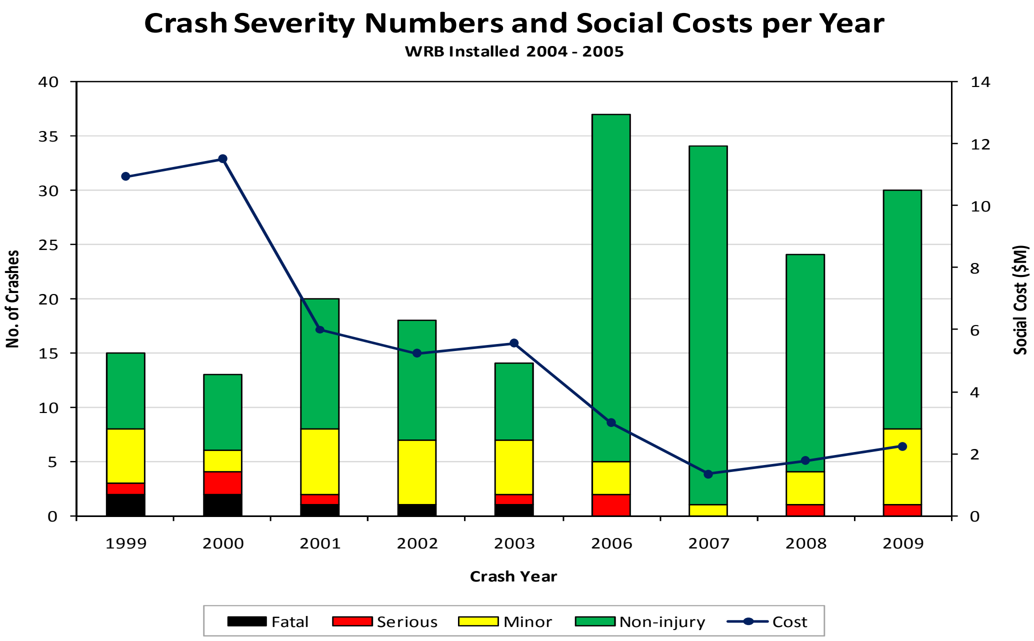
In 2004/05 a central median wire rope barrier (WRB), based on the Swedish 2+1 system, was installed on a 9km section of State Highway 1 between Auckland and Hamilton.

While the installation required compromises to be made, and there has been a significant increase in the number of crashes post-installation, there has been a correspondingly significant reduction in crash severity.

A number of issues are associated with the performance of the installed WRB, from which solutions have been identified, that can be applied to existing and future WRB installations.

The frequency of barrier strike appears to be related to the relatively narrow median on which the WRB was installed and the curved alignment. A wider median could have reduced the potential for barrier strikes, accommodated deflection of the barrier during a crash, improved visibility for drivers and better facilitated maintenance operations. However, there were potentially significant construction cost implications associated with this.

The key conclusion of the paper is that, even in cases where some design compromises are required, an appropriately installed and maintained WRB system, even on a narrow median, can substantially reduce the severity of crashes along a section of highway.



20 Case study referenced from paper 'Longswamp to Rngiriri wire Rope Barrier increased crash numbers but improved road safety'. Crowther S, Swears. ARRB 2010 Conference

Our contact details

NZ Transport Agency National Office
50 Victoria Street
Private Bag 6995
Wellington 6141
New Zealand

Telephone: 04 894 5400
Fax: 04 894 6100

NZ TRANSPORT AGENCY
WAKA KOTAHI

New Zealand Government