Developing an optimised safety management philosophy reflecting the Safe System in a constrained environment

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ABSTRACT

A key feature of Safer Journeys, the New Zealand Governments guiding document for road safety over the next decade, is the introduction of the Safe System and consequent focus on reducing death and serious injury. The relatively rare nature of high severity crashes, those resulting in death or serious injury, combined with the increasing pressure on both maintenance and improvement funding has resulted in a need to reassess how safety is managed on the New Zealand State Highway Network.

This paper looks at how the NZ Transport Agency has combined data and assessments from the New Zealand Road Assessment Programme (KiwiRAP), with level of service criteria, and both proactive and reactive risk assessment to determine the optimal road safety management/treatment philosophy for road corridors.

1. INTRODUCTION

1.1 BACKGROUND

New Zealand's accident blackspot crash reduction programme, originally developed in the mid 1980's, has been the primary road safety improvement strategy for many decades. Up until 2004, when formal monitoring of the programme ceased, some 4294 sites had been studied and entered into the monitoring system with all recommended works having been completed at 2487 sites (LTSA,2004). Monitoring of completed sites found:

- An average reduction of 35% in reported injury crashes, with
- Fatal crashes reducing 49%,
- Serious injury crashes reducing 38% and
- Minor injury crashes reducing 33%, with an
- Average benefit cost ratio of 28.

While this approach has served New Zealand well for some 25 years the downside includes:

- only specific locations along a corridor are improved, and only as a reactive response to crashes,
- the level of improvement at a location has varied according to the available benefits and qualifying benefit cost criteria,
- the sections of highway between improvement sites and without a significant crash history often remain unimproved, resulting in
- an increasingly inconsistent network.

In addition to the above, the simple focus on crash numbers has seen many of the same sites being investigated every five years or so, even though the scope for further low to medium cost improvements was limited. While in lower volume networks in particular, there has been an increasing focus on sites with clusters of minor injury crashes.

Toward the end of the previous decade it became increasingly obvious that a reliance on crash cluster identification and treatment was not going to generate the desired reductions in death and serious injury because:

- the proportion of fatal and serious crashes that occurred at traditional blackspots[1] was low, and
- the rate at which blackspots were being treated was also low.

[1] A blackspot has traditionally been defined as a cluster of crashes including 2 or more high severity crashes or at least 5 injury crashes in 5 years, within either a 30m radius in areas with a speed limit of ≤ 70km/h or 250m radius in areas with a speed limit > 70 km/h.

1.2 SAFER JOURNEYS

In 2010 the Government released Safer Journeys (Ministry of Transport 2010), the government's strategy to guide improvements in road safety over the period 2010–2020. Key features of Safer Journeys included the vision of a "safe road system increasingly free of death and serious injury", supported by the adoption of the Safe System approach to road safety.

The focus on a reduction in death and serious injury, as opposed to reducing crashes of all severities, required a re-evaluation of the approach to road safety, as these high severity crashes, that are the focus of Safer Journeys, are highly dispersed geographically:

- 29% of the high severity crashes occur at locations that would have previously have been known as blackspots, while
- 44% of high severity crashes occur at locations where there has been no other injury crash reported in the past 5 years.

1.3 APPROACH AND STRUCTURE

This paper documents the new approach to managing road safety improvements which has been applied in the first instance to the New Zealand State Highways. Even though the State Highway network accounts for roughly 12% of New Zealand's total road network:

- it carries around half of the national vehicle kilometres of travel and
- Crashes on the State Highway network account for:
  - 52% of fatalities, and
  - 36% of the serious injuries, or
  - 38% of high severity outcomes

From a "targeting to risk perspective" it makes sense to focus any new approach to safety management on the State Highways. However, more is known about the State Highways in terms of the roads themselves, the surrounding environments, and the volumes of travel. This has facilitated the development of the New Zealand road assessment programme KiwiRAP (KiwiRAP, 2010) and the development of High Risk Rural Roads Guide (NZTA 2011), two recent initiatives that underpin this new approach to managing road safety; each is discussed in subsequent sections.

1.4 RISK

One of the key First Actions specified within the Safer Journeys Action Plan (Ministry of Transport 211) was the requirement to focus improvements on high risk rural roads. Before looking at the development and use of KiwiRAP and the High Risk Roads Guide, it is worth considering the question: *What is a high risk [rural] road ?*

It is important to understand that risk can be defined in many ways, with the two most applicable to managing highway safety being:

Collective Risk - a measure of crash density expressed as crashes (in this case those resulting in death or serious injury), per kilometre, per year.

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

Personal Risk - the risk of a particular individual being involved in a crash (in this case those resulting in death or serious injury), as a result of travelling a distance on the route, measured as crashes per unit of travel (typically 100 million vehicle kilometres).

$$\text{Personal risk} = \frac{\text{Fatal crashes} + \text{serious crashes}}{\text{VKT}/10^8}$$

VKT= length of road in km x number of years of data x 365 days x AADT)
AADT = annual average daily traffic

The subsequent sections of this paper look at how alternative measures of collective and personal risk can be calculated and how these alternatives are brought together to determine the appropriate safety management philosophy; one that recognises that under constrained conditions it is not possible to create all roads equally.

2. KiwiRAP

KiwiRAP is the New Zealand Road Assessment Programme. As with other road assessment programmes KiwiRAP has three data protocols:

- Risk Mapping
- Star Rating, and
- Monitoring.

In this paper we are concerned with the first two only.

2.1 RISK MAPPING

Under this protocol two sets of crash risk maps were published in 2008, based on fatal and serious crashes reported as having occurred on State Highways during the period 2002 to 2006 inclusive.

The State Highway network was divided into approximately 172 routes, ranging in length from 7.3 km to 317.8km, average approximately 60 km. This was 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. As per the RAP protocol, for each route maps of both Collective and Personal crash risk were produced.

In each case the risk maps use a 5 category rating system ranging from High, through Medium to Low, with approximately 20% of the links (by number) being allocated to each band (Figure 1).

While the KiwiRAP risk maps provided a means of identifying high risk routes the way in which these state highway links were selected had two effects:

1. Many of the high collective risk links are shorter higher-volume sections typically located in the North Island, and
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 was 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

2.2 STAR RATINGS

The KiwRAP star rating provides a measure of the safety related road infrastructure, rating roads from 1 star to 5 star (poor to excellent). The star rating is derived from three component road protection scores representing the risk of a:

- Head-on crash
- Run-off-road crash, and an
- Intersection crash

Together these three crash types account for 89% of the death and serious injury on New Zealand’s rural roads.

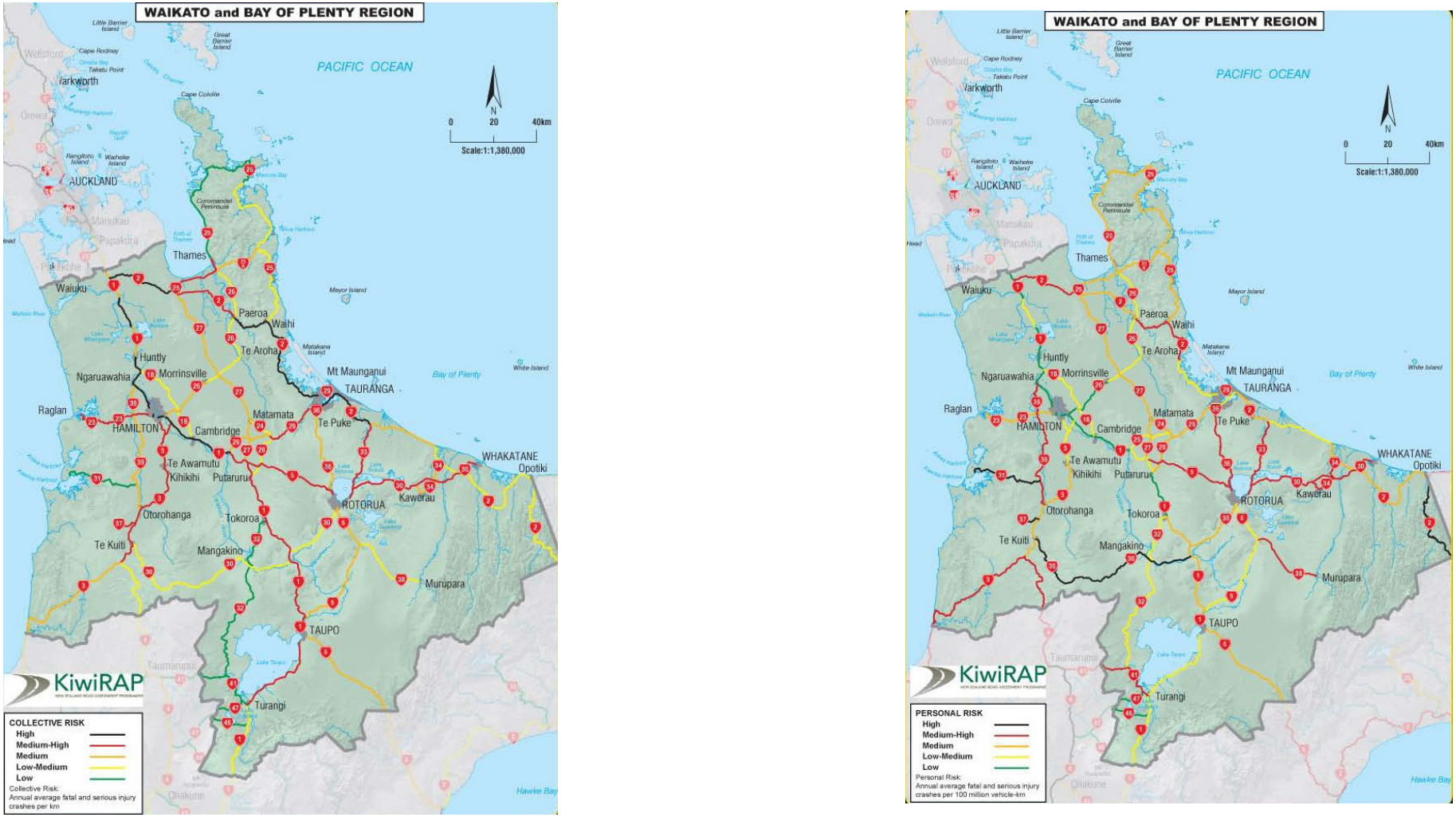


Figure 1 Example of KiwiRAP risk maps (left -collective risk right- personal risk)

The three road protection scores are calculated using separate combinations of 18 infrastructure variables (see Table 1), which national research and international literature identify as impacting on road safety performance.

Mid-Block Attributes	**Intersection Attributes**
Road Type	Intersection Type
Annual Average Daily Traffic	Side Road Category
Lane Width	Alignment of Legs
Sealed Shoulder Width	Sight Distance
Horizontal Alignment	Right Turn Provisions
Speed Environment	Left Turn Provisions
Terrain	**Rail Crossing Attributes**
Overtaking Provision	Crossing Control Type
Offset and severity of roadside hazards	Train Frequency

Table 1 KiwiRAP Star Rating Variables

The KiwiRAP Star Rating, provides a proactive measure of safety, as it does not rely on crashes to occur. However, one of the strengths of the KiwRAP Star Rating model is the strong correlation between the Star Rating and historic safety performance measured in terms of the personal crash risk (Figure 2).

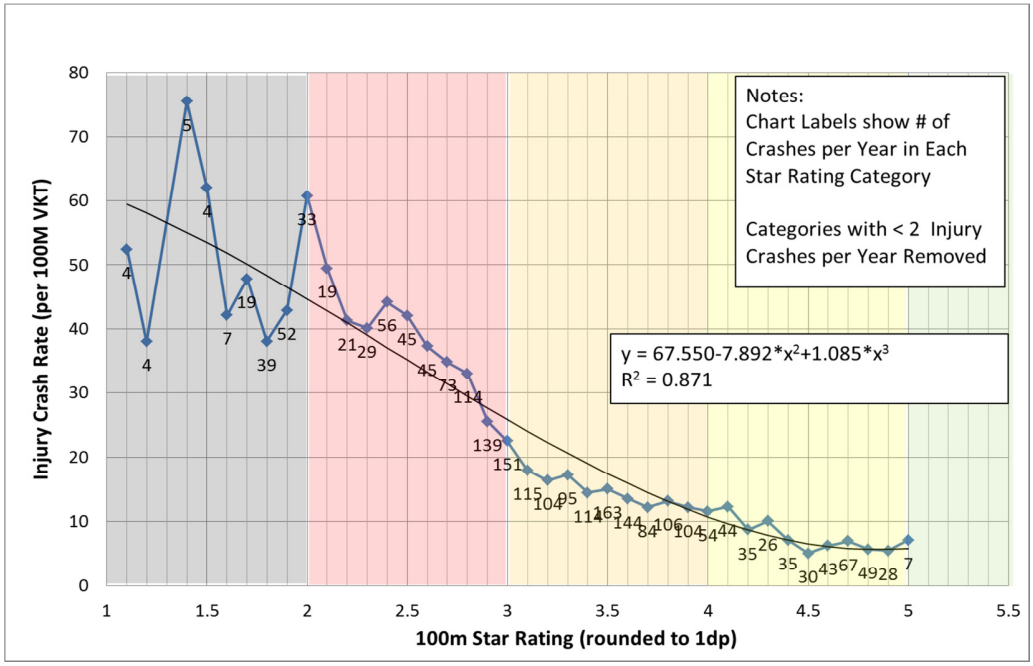


Figure 2 The Relationship Between KiwiRAP Star Ratings versus Injury Crash Rate

The fact that the model accounts for 87% of the variation injury crash rate allows the star rating to be used as a proactive measure of personal risk and when multiplied by the annual average daily traffic volume, as a proactive measure of collective risk.

2.3 NETWORK CLASSIFICATION

The KiwiRAP star rating has also been linked to the customer levels of service associated with the road network classification (NZTA 2013), as shown in Table 2.

Road Classification	KiwiRAP contribution to Safety Level of Service
High Volume	Equivalent to KiwiRAP 4-Star standard.
National Strategic	A high KiwiRAP 3 or 4-star
Regional Strategic	Mostly KiwiRAP 3-star equivalent or better
Arterial	Not Applicable
Primary Collector	
Secondary Collector	
Access	

Table 2 KiwiRAP Star Rating Targets by Road Classification

3. HIGH RISK RURAL ROADS

Although the KiwiRAP Risk Maps provide reactive measures of Collective and Personal risk, the lengths of route used in the analysis are considerable. 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. There was a concern that should safety improvements on these long routes receive funding priority simply because they occurred on a black or high risk route, there could be a mis-allocation of funding.

In order to address these “short comings” it was necessary to develop a more general method for identifying high risk rural roads.

A sliding window routine, developed by consultants MWH New Zealand Limited, was used to interrogate the State Highway network. The routine looks at the crashes within a window of user defined length (5000m in Figure 3). The window is then moved along each highway according to the user defined offset (1000m in Figure 3), and the crashes within the window are reported for each increment.

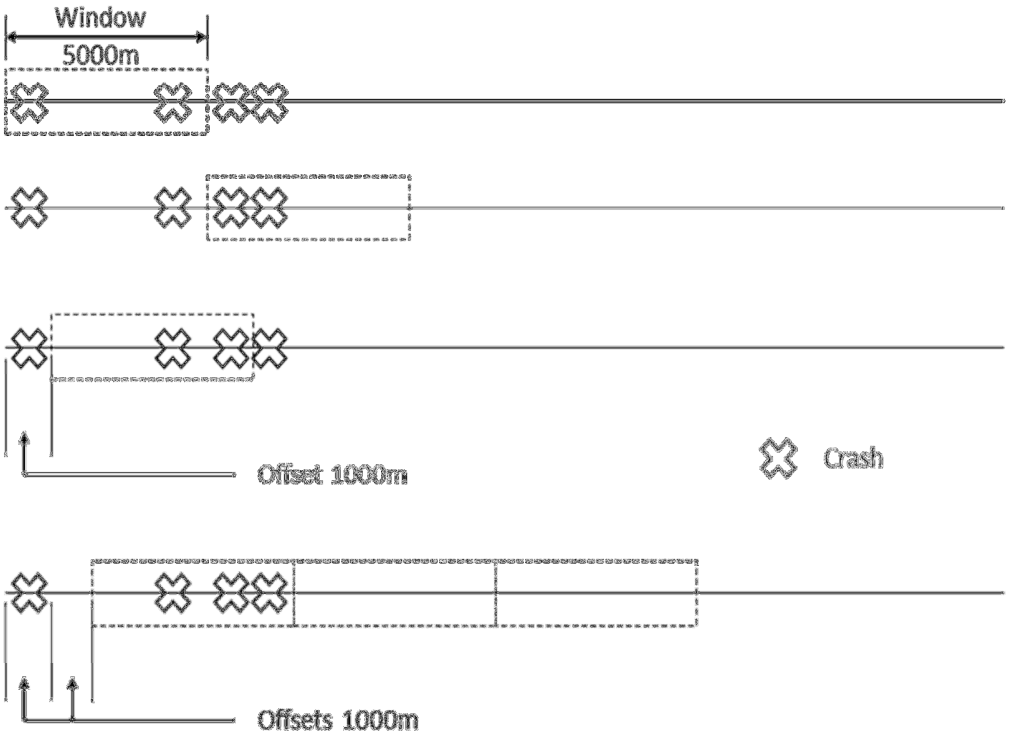
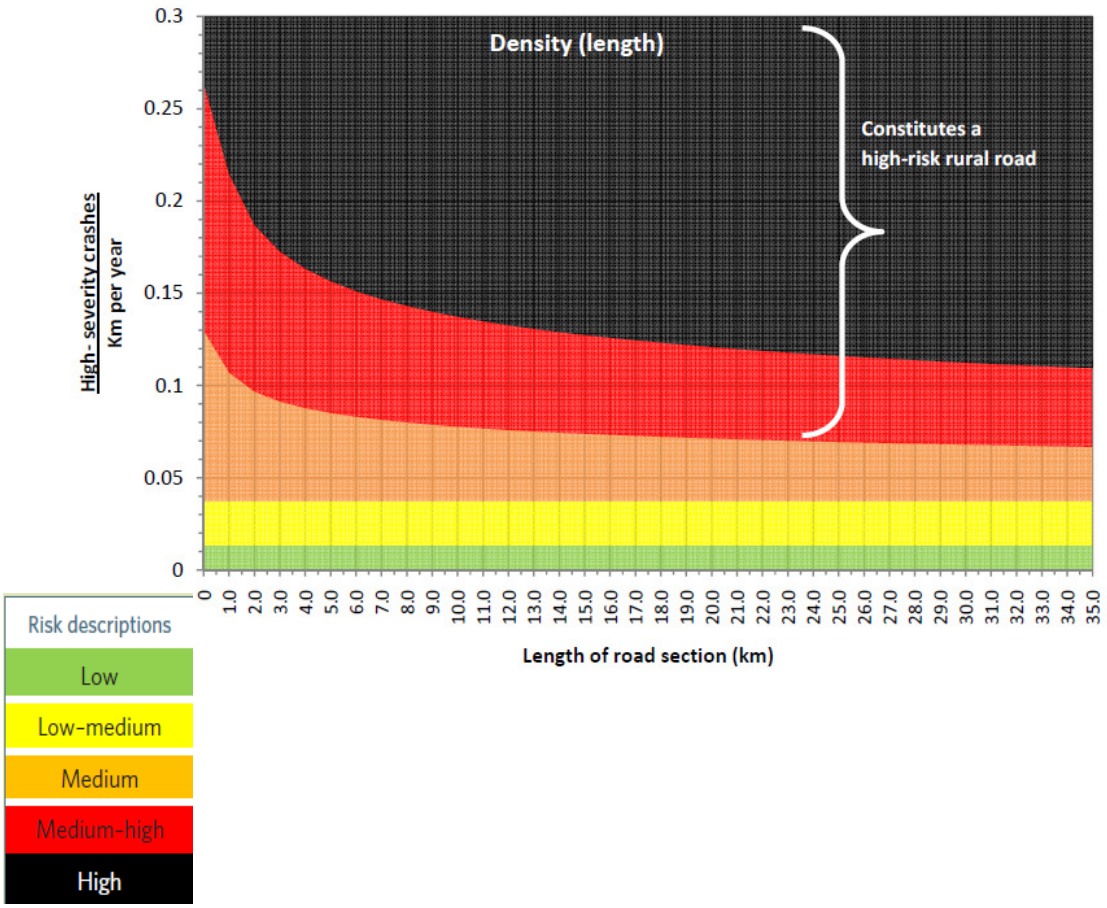


Figure 3 Sliding window approach

The sliding windows approach was run over a range of window lengths from 2 km through to 30 km: lengths below 2 km were considered to be better covered by crash cluster analysis, while those greater than 35 km would be covered by the KiwiRAP risk maps. For each traffic volume band the risk distributions were divided into 5 bands each of 20%, representing the five risk bands as shown in Figure 4.



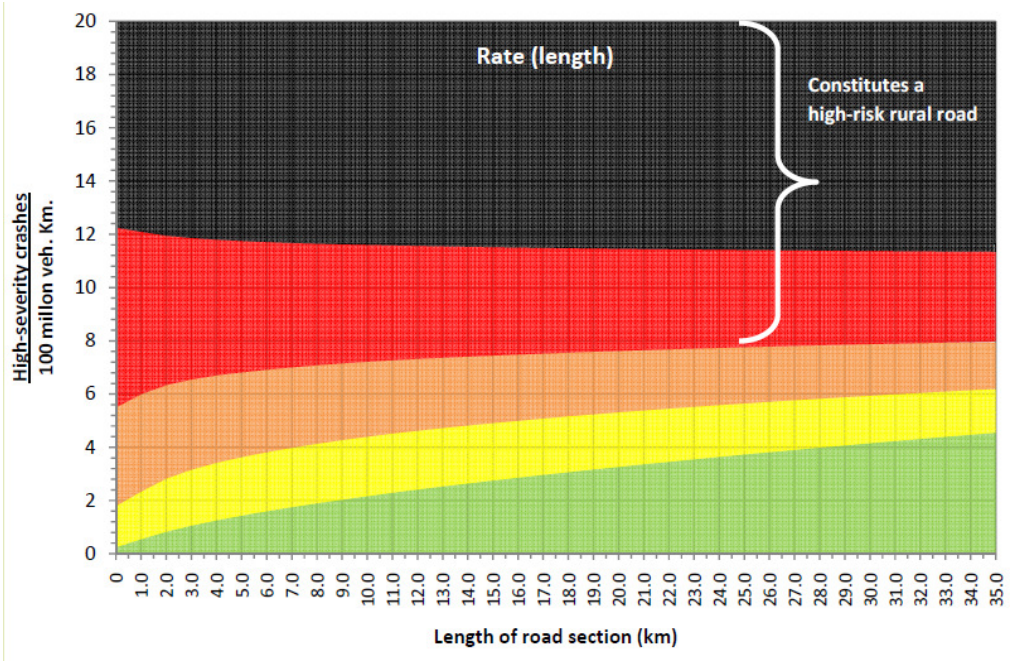


Figure 4 Collective and Personal risk rating

4. BRINGING IT ALL TOGETHER

The result of KiwiRAP and High Risk Rural Roads identification exercises outlined above, is a range of reactive and proactive measures of collective risk and personal risk, together with aspirational infrastructure standards based on the highway classification. Now the trick is to bring these measures together to identify what is the broad treatment philosophy that should apply to a particular road section.

4.1 COMBINING COLLECTIVE & PERSONAL RISK

Irrespective of the method used to calculate collective and persona risk the result is essentially a five by five matrix of Personal Risk (rows) and Collective Risk (columns), as shown in Figure 5. This five by five matrix, can then be simplified into effectively four quadrants. These four quadrants define the most appropriate safety management and improvement strategies.

Figure 5 Assessing the appropriate improvement strategy (source NZTA 2011)

In the upper right quadrant of Figure 5 there are those roads with both high personal and high collective risk, there is significant crash reduction potential on these roads and it is likely that major transformation projects will be viable. At the other extreme there are roads with both low Collective Risk and low Personal risk. These roads require only maintenance and little in the way of safety improvements will be required or justified.

The lower right quadrant contains those roads with high Collective Risk but low Personal Risk. Roads in this quadrant have higher traffic volumes and while not necessarily able to support major transformation projects such as grade separated interchanges, these roads will benefit from medium cost corridor treatments such as wider lane or shoulder works, roadside hazard management and median barriers.

The upper left quadrant contains those roads with relatively low traffic volumes and therefore lower Collective Risk but high Personal Risk. It is unlikely that even medium cost treatments will be economically viable on these roads. Although blackspot or crash cluster treatments will still deliver benefits at key locations, the most appropriate safety management strategy will revolve around improvements in delineation and markings, road surface maintenance and speed management.

The treatment selection strategy, Figure 5, can be determined using Collective and Personal Risk, as well as alternative measures of personal risk based on the KiwiRAP Road Protection Score and Star Rating and a local inspection methodology known as RISA (road infrastructure safety assessment) an observational forerunner to KiwiRAP designed principally for local roads (NZTA 2012).

4.2 SELECTING THE TREATMENT PHILOSOPHY

While Figure 5 provides the basis for a simple explanation regarding the use of Collective and Personal risk measures, it is not completely correct. It is highly unlikely that a highway would move from the upper left quadrant (Safety Management) to the upper right quadrant (Safe System Transformation) without passing through a phase of Safer Corridors. In practice the real picture is that shown in Figure 6.

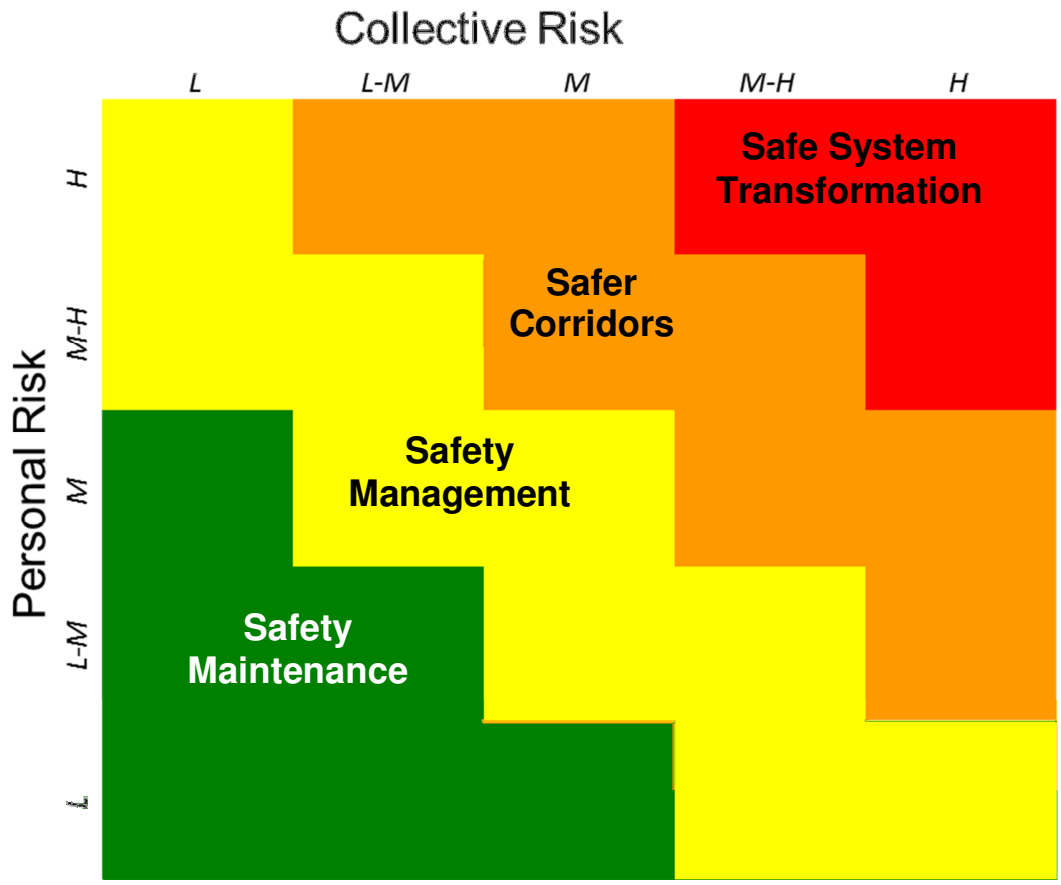


Figure 6 Selection of the appropriate treatment strategy

4.3 TREATMENTS

Once the appropriate treatment philosophy has been agreed the High Risk Rural Roads guide then provides a range of possible treatment types aimed at addressing the three key crash types, Head-on, Run-off-road and Intersection crashes together with options for the treatment of crashes involving vulnerable road users. Examples of such treatments are shown in Table 3.

Key Crash Type	Safe System Transformation Treatments	Safer Corridors Treatments	Safety Maintenance Treatments
Head-On	• Median barriers • Safe system speeds	• Marked median treatments • ATP markings • Improved delineation • Active warning signs • Harm reduction speeds	• Increased intervention levels • Increased 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 • Increased skid resistance • Planting policies • Hazard removal
Intersections	• Grade-separated interchanges and overpasses • Roundabouts • Safe system speeds	• Wider shoulders and separated turning facilities • Improved delineation • Active warning signs • Harm reduction speeds	• Increased intervention levels • Increased skid resistance • Hazard removal • Improved sight visibility
Vulnerable Road Users	• Separated off-road facilities • Safe system speeds	• Wider shoulders and separated turning facilities • Improved delineation • Harm reduction speeds	• Improved sight visibility • Reduce pinch points • Consistent shoulder width and surface quality

Table 3 Examples of treatments appropriate to each safety management philosophy (source NZTA 2011)

5. SUMMARY

The publication of Safer Journeys, the New Zealand Governments strategy for managing road safety through to 2010, saw an increased focus on reducing death and serious injury on New Zealand's roads. It became clear that a traditional blackspot programme was not going to deliver the necessary road safety improvements, and a new proactive approach was developed using both the KiwiRAP road assessment programme and the High Risk Rural Roads Guide.

6. REFERENCES

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Author Biographies

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Fergus Tate is the National Manager, Traffic and Safety with the New Zealand Transport Agency. A Chartered Professional Engineer, Fergus holds a New Zealand Certificate in Engineering and a Batchelor of Engineering (Civil) as well as a MSc and PhD from Leeds University (UK). Fergus has over 30 years' experience ranging from highway construction and maintenance management, professional services consultancy, high level research and academic projects, to policy development and performance monitoring.

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Colin Brodie is the Chief Advisor Road Safety with the New Zealand Transport Agency. Colin has 40 years' experience in the roading industry for both the Government and the private sector. He started out in design, moved into traffic engineering before specialising in Road Safety over the last two decades.

Colin is the New Zealand representative on the Austroads Safety Task Force leading their research programme in the road engineering field. He is also the technical director for the New Zealand Road Assessment Programme, KiwiRAP.