

## **Targeting High Risk Intersections**

Brodie, C.<sup>1</sup> Durdin, P.<sup>2</sup> Tate, F.<sup>1</sup> Mackie, H.<sup>3</sup>

<sup>1</sup> New Zealand Transport Agency

<sup>2</sup> Abley Transportation Consultants

<sup>3</sup> Mackie Research and Consulting

### **Abstract**

The New Zealand Transport Agency has recently published the High-Risk Intersections Guide. The guide introduces new assessment techniques that enable intersections with a high-risk of someone dying or being seriously injured in the future to be identified. The assessment techniques have been developing using industry knowledge of the inter-relationships between speed environment, the intersection form and control type and crash movements to estimate risk. The departure from a wholly reactive approach to road safety allows high-risk intersections to be identified before people are killed or seriously injured, which is a positive step for promoting and providing a safer road environment in New Zealand.

Given the finite resources available to improve road safety it is imperative that road safety investigations and investments are targeted at the highest risk parts of the network to maximise the likelihood that projects will deliver the greatest road safety benefits. The High-Risk Intersections Guide is already being used by the New Zealand Transport Agency and Road Controlling Authorities to target road safety efforts and investment. To address high risk rural intersections in a cost effective manner the NZ Transport Agency is trialling vehicle activated speed limit reduction signs. The initial results of these are promising.

This paper will be of interest to everyone involved with the targeted identification, prioritisation and funding of road safety projects.

## Introduction

The ‘High-Risk Intersections Guide’ (NZTA, 2013) provides practitioners with best practice guidance to identify, target and address key road safety issues at high-risk intersections. It has been prepared by the NZTA to provide guidance on the Government’s Safer Journeys 2020 Strategy (MoT, 2010) initiative to focus efforts on high-risk intersections.

The High-Risk Intersections Guide focuses on identifying intersections with an established or estimated occurrence of fatal and serious injury crashes, as opposed to crashes that result in less severe outcomes. The incorporation of proactive techniques allows high-risk intersections to be identified before people are killed or seriously injured, which is a positive step for promoting and providing a safer road environment in New Zealand.

## Assessing Risk of Death and Serious Injury

A number of inter-related factors associated with road design, speed, vehicles and road use contribute to the likelihood and severity of intersection crashes (NZTA, 2013).

High-risk intersections are broadly defined as those intersections that have a history of reported Fatal or Serious crashes or an estimated number of Death and Serious injury (DSi) casualty equivalents, based on all injury crashes, that suggest a disproportionately higher than normal risk that someone will be killed or seriously injured in the future (NZTA, 2013). It is important that these intersections are identified because they are the places where targeted safety improvements are likely to be most successful at preventing deaths and serious injuries from occurring in the future.

The High-Risk Intersections Guide sets out the technique for estimating the DSi casualty equivalents for an intersection. It does this by combining knowledge of the inter-relationship between speed environment, the intersection form and control type and crash movement type factors. This approach acknowledges that some crash movement types are likely to result in more severe outcomes than others.

Different intersection types and controls also affect the typical severity of a crash. Roundabouts in particular have a lower crash severity profile than priority or signalised intersections because the crash impacts in multi-vehicle crashes are minimised through controlled entry speeds and the angle of collision.

## Risk Metrics

The High-Risk Intersections Guide defines two main types of risk metric: Collective Risk and Personal Risk.

- **Collective Risk** is measured as the total number of fatal and serious crashes or deaths and serious injuries within 50 metres of an intersection in a crash period.
- **Personal Risk** is the risk of death or serious injuries per 100 million vehicle kilometres travelled within 50 metres of an intersection.

## Collective Risk

There are two methods for defining Collective Risk.

According to the High-Risk Intersection Guide, the simplest definition of Collective Risk is to consider the number of fatal and serious crashes that have occurred at an intersection in a period of time; normally five or ten years. However, using these crashes alone can be fraught with the risk of reaching false conclusions about crash risk based on small numbers. It can

easily result in road controlling authority’s addressing randomly occurring crashes within the network (NZTA, 2013).

For this reason, the criteria are set fairly high to minimise the risk of falsely identifying sites that are not high-risk. To be confident that an intersection is high-risk there needs to be three or more serious and/or fatal crashes in five years (or five or more serious and fatal crashes in ten years). However even with such thresholds, only about 80 intersections in New Zealand have three or more fatal and serious crashes in a five-year period.

The second definition involves the estimation of the number of DSI casualty equivalents based on all injury crashes that have occurred at an intersection. It involves the multiplication of each reported injury crash at an intersection by the corresponding Severity Index ratio. Severity indices have been calculated for each primary crash movement type, for five different intersection forms and control types in both urban and rural speed environments. A ‘Severity Index’ is the expected ratio of Death and Serious injury (DSI) casualties to all injury crashes.

Severity indices indicate which crash movement types for a specific intersection type in a defined speed environment are more or less likely to result in a high-severity outcome. The Severity Indices acknowledge that different crash movement types are more or less likely to result in road users being killed or seriously injured. For example, crashes involving drivers turning right out of a side road typically result in more severe injuries than rear end collisions.

The DSI casualty equivalents method acknowledges that actual fatal and serious crash data alone is not a good indicator of the underlying risk of a high-severity crash at many intersections. It is especially effective at identifying intersections with a moderate reported crash rate, but have an incidence of crashes with high Severity Indices suggestive of any similar future crashes at that intersection having a high probability of next crash being high severity.

The Collective Risk thresholds based on the estimated DSI casualty equivalent approach is set out in Table 1. The thresholds have been determined by analysing a large number of existing intersections, and set so that Medium High and High Collective Risk intersections together make up approximately 5% of all intersections in New Zealand.

<p><b>Table 1</b></p> <p>Criteria for Identifying Intersection Collective Risk</p>	
<b>Risk Category</b>	<b>Collective Risk Thresholds (estimated DSI casualty equivalents)</b>
Low	<0.3
Low Medium	0.3 - <0.6
Medium	0.6 - <1.1
Medium High	1.1 - <1.6
High	≥1.6

Intersections that are assessed as having a ‘Medium High’ or ‘High’ Collective Risk are deemed to be high-risk intersections (NZTA, 2013).

## Personal Risk

Personal Risk measures the risk to each person using the intersection. In practice only the number of motor vehicles is routinely available, so the personal risk is calculated from the collective risk divided by a measure of traffic volume exposure. Intersections with the highest risk per vehicle are ranked as the worst from a Personal Risk perspective.

The measure of traffic exposure used to calculate Personal Risk is based on the product of the conflicting flows entering from each approach (Product of Flow). In theory, the crash risk would follow a relationship that is the square root of the conflicting flows (mathematically raising the product to the power of 0.5), but in practice, raising the flows to a power of 0.4 provides a better straight line fit to the crash data, and better compensates for the reduced risk that is observed at higher traffic flows.

The daily Product of Flow formula (PoF) is:

$$PoF = \left( \text{average}(Q_{major_1}, Q_{major_2}) \cdot \text{average}(Q_{minor_1}, Q_{minor_2}) \right)^{0.4}$$

- Qmajor 1 and 2 = the two-way link volume (AADT) on each leg of the major road.
- Qminor 1 and 2 = the two-way link volume (AADT) on each leg of the minor road. At a T intersection the same equation is applied, but with  $Q_{minor_1}$  set as the side road AADT, and  $Q_{minor_2}$  defined to be zero.

To generate a reliable estimate of Personal Risk, this risk metric is only calculated for intersections with four or more recorded injury crashes in the past five years. This overcomes reaching potentially misleading conclusions about the risk of intersections with low traffic volumes, which are especially sensitive to small changes in crash numbers.

As with Collective Risk, a key issue is to understand how reflective the crash history is of the underlying DSI crash risk. For this reason, the Personal Risk calculation is based on the greater of the ‘Reported Fatal & Serious crashes x 0.5’ or ‘Estimated DSI casualty equivalents’ calculated over a five year period.

The traditional traffic exposure measure that is used in road safety analysis is crashes per 100 million vehicle kilometres travelled. So the Personal Risk metric is also adjusted to represent DSI casualty equivalents per 100 million vehicle kilometres travelled.

The Personal Risk calculation formula is:

$$= \frac{\max(\text{reported F\&S crashes} \cdot 0.5, \text{estimated DSIs based on severity indices}) \cdot 10^8}{\left( \text{average}(Q_{major_1}, Q_{major_2}) \cdot \text{average}(Q_{minor_1}, Q_{minor_2}) \right)^{0.4} \cdot 5 \text{ years} \cdot 365 \text{ days} \cdot 1.7}$$

The 1.7 value on the bottom line of the Personal Risk formula is a conversion factor to make the exposure equivalent to vehicle kilometres travelled through the intersection.

The Personal Risk thresholds based on the estimated DSI casualty equivalent approach is set out in Table 2. The thresholds have been determined by analysing a large number of existing intersections, and set so that Medium High and High Personal Risk intersections together make up approximately 5% of all intersections in New Zealand.

**Table 2**

Criteria for Identifying Intersection Personal Risk	
<b>Risk Category</b>	<b>Personal Risk Thresholds (estimated DSI casualty equivalents)</b>
Low	<6
Low Medium	6 - <10
Medium	10 - <16
Medium High	16 - <32
High	≥32

Intersections that are assessed as having a ‘Medium High’ or ‘High’ Personal Risk are deemed to be high-risk intersections (NZTA, 2013).

### Level of Safety Service

Level of Safety Service (LoSS) is a measure of actual intersection safety performance relative to that expected based on a reference set of intersections. A conceptual framework for using LoSS to identify dangerous sections of road was formalised by Kononov and Allery (2003) in North America, under the name Level of Service of Safety. This was included as a performance measure in the Highway Safety Manual (AASHTO, 2010), and extended to intersections. Ideas from this publication were drawn on to develop existing work by Durdin (2010) into LoSS as it now exists in the High Risk Intersections Guide.

The LoSS method defined in the High-Risk Intersections Guide is derived from the general flow crash prediction models contained within the NZTA’s Economic Evaluation Manual (NZTA, 2010). The method takes into account the speed environment, intersection form and amount of traffic travelling through an intersection.

The injury crash performance of an intersection has been separated into five LoSS bands as shown in Table 3.

**Table 3**  
Level of Safety Service Bands

<b>Level of Safety Service (LoSS)</b>	<b>Safety Performance</b>	<b>Definition</b>
LoSS I	0-30 <sup>th</sup> percentile	The observed injury crash rate is lower (better) than that expected of 30% of similar intersections.
LoSS II	30 <sup>th</sup> -50 <sup>th</sup> percentile	The observed injury crash rate is lower (better) than that expected of 50% of similar intersections, and higher than that of 30%.
LoSS III	50 <sup>th</sup> -70 <sup>th</sup> percentile	The observed injury crash rate is lower (better) than that expected of 70% of similar intersections, and higher (worse) than that of 50%.
LoSS IV	70 <sup>th</sup> -90 <sup>th</sup> percentile	The observed injury crash rate is in the worst 30%, lower (better) than that expected of 90% of similar intersections,

Level of Safety Service (LoSS)	Safety Performance	Definition
		and higher (worse) than that of 70%.
LoSS V	90 <sup>th</sup> -100 <sup>th</sup> percentile	The observed injury crash rate is in the worst 10 percent band - higher (worse) than that expected of 90% of similar intersections.

Intersections where the actual injury crash performance is substantially greater than the predicted injury crash performance (LoSS IV and V) can be suggestive of a fundamental deficiency with the intersection. In some instances these deficiencies can be addressed with lower cost countermeasures, such as modifications to signal coordination, controlling approach speeds or improving sight distances. It is important to note that LoSS is a prioritisation technique that only compares an intersection against other intersections of the same form. Therefore those intersections where the actual injury crash performance is better than the predicted injury crash performance (LoSS I and II), but have high Collective or Personal risk metrics are likely to require safe system transformation countermeasures to deliver safety improvements, such as changes the intersection form.

For instance a priority rural crossroad with a medium LoSS could still have a high collective risk and conversion to a roundabout is likely to be much more effective than improvements under the same control type. The relative safety performance of different intersection controls with varying traffic volumes is presented in the High-Risk Intersections Guide. This enables the change in DSI casualty equivalents that could be expected from a transformation to a different control to be estimated. This can be compared with the existing DSI casualty equivalents to estimate the potential to crash saving benefits that might be achieved from a transformational change.

The LoSS indicator adds an extra dimension to the understanding of intersection safety performance. It provides a consistent and straightforward method for national, regional and local Road Controlling Authorities to assess their intersections against comparable intersections from around New Zealand (Cockrem et al. 2013). It enables practitioners to identify those intersections where road safety benefits are most likely to be realised, and indicates what type of improvement is likely to be most appropriate. The indicator is likely to have a significant impact on how transport professionals prioritise safety improvement budgets and work. This approach helps to highlight intersections that perform poorly compared to similar intersections, even if their total or per-vehicle crash rate is not high enough to make them stand out.

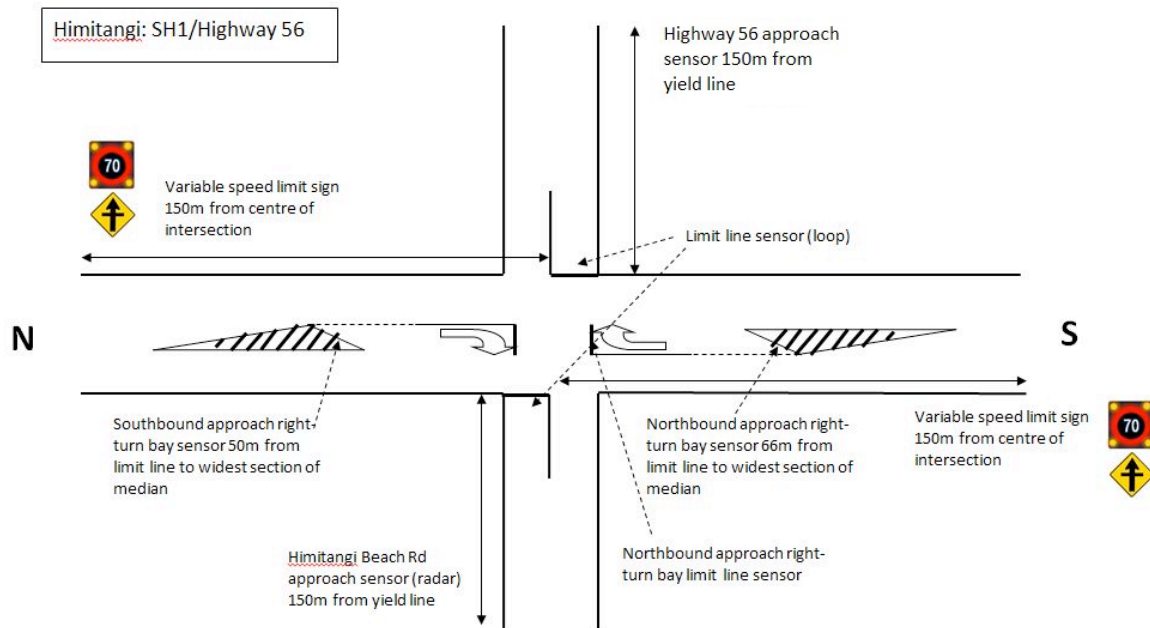
### **Rural Intersection Activated Warning System**

One novel lower cost treatments being trialled at a selection of rural high collective risk intersections is the Rural Intersection Activated Warning System (RIAWS). RIAWS lowers the speed limit through the intersection to 70 km/h speed limit when potential conflict situations exist i.e. the presence of a side road or right turning vehicle on the main road. This is achieved by activating variable speed limit signs on the main road when potentially conflicting vehicles trigger side road or right turn bay sensors.

The RIAWS consists of the following elements (Figure 1 and 2):

- Side-road radar sensors (high definition radar) to detect approaching side road traffic approximately 150m from the intersection and activate signs.

- Side-road limit line sensors (cut loops) to detect waiting traffic and trigger the end of sign activation following a delay.
- Right turn bay sensors 50-66m from limit line, to activate signs, plus limit line sensors to detect queuing traffic and terminate sign activation following a delay.
- Variable speed limit signs approximately 150m from intersection.
- A central control system box to manage the system and accommodate data collection equipment.



**Figure 1. Basic outline of RIAWS componentry (Mackie Research & Consulting, 2013)**



**Figure 2. Himitangi RIAWS trial site**

The RIAWS site on State Highway 1 has been operating since January 2013. This trial and a second installation in Christchurch City are being closely monitored, a further four sites are currently planned. The monitoring programme includes the collection of speed profiles through the conflict zone, road users perception surveys and analysis of gap acceptance

behaviour. Early results indicate speeds through the conflict zone have dropped by around 20km/h and a high level of user understanding and acceptance.

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