ENHANCED IDENTIFICATION OF HIGH RISK INTERSECTIONS

***Authors*:**

Haris Zia (Presenter)
BE(Hons) GIPENZ
Graduate Transportation Engineer
Abley Transportation Consultants Ltd
Contact: haris.zia@abley.com

Paul Durdin
BE(Hons), CPEng, MIPENZ
Director
Abley Transportation Consultants Ltd
Contact: paul.durdin@abley.com

ABSTRACT

The New Zealand Transport Agency's High-Risk Intersections Guide introduces new assessment techniques for identifying the risk of someone dying or being seriously injured in the future at an intersection. The assessment techniques have been developed using industry knowledge of the inter-relationships between speed environment, 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.

This paper presents the development of a GIS-based mechanism for calculating the risk profile of all intersections in a town, city or region in a cost-effective and time-efficient manner compared to the manual equivalent. Aside from enabling Road Controlling Authorities to make informed decisions about prioritising road safety countermeasure improvements, the process has helped unlock the true value of the transport related data that organisations often put great effort and expense into collecting. The paper goes on to demonstrate the robustness of the risk estimation process by comparing recent fatal and serious crashes at intersections against prior risk estimates of the occurance of those high severity crashes.

TRADITIONAL SAFETY APPROACHES

The traditional approach of identifying and addressing road safety issues at intersections in New Zealand has generally been targeted on the basis of historic crash performance; through crash reduction studies, and black-spot analyses and treatments. While these crash clustering approaches served New Zealand well in the past, it tended to place a strong emphasis on crashes with minor injuries.

Alternative approaches were introduced to overcome this, including the ranking of sites by the social cost of crashes. However, this had the opposite effect and ended up placing excessive focus on recent fatal crashes. As fatal crashes very rarely occur at the same location within a five-year period, the approach of prioritising sites for treatment based on social crash costs is fraught with the risk of reaching false conclusions about crash risk because of a low number of observations. Prioritising in this manner also drew criticism from the general public who were unaccepting of an approach of waiting for someone to die or be seriously injured before the funding of improvements could be justified.

The relative rarity of fatal and to a lesser extent serious crashes at the same site is evidenced from analysis of crash data in Auckland. Analysis of crash data at intersections in 2013 showed that 79% of fatal and serious crashes occurred at sites with no previous fatal or serious crashes in the previous 5 years and 64% occurred at sites with 2 or fewer injury crashes in the same period. This suggests that an approach of prioritising based on previous fatal and serious crashes in particular, is not a strong indicator of a high probability of future fatal and serious crashes.

SAFER JOURNEYS, NEW ZEALAND’S ROAD SAFETY STRATEGY

Safer Journeys, New Zealand’s Road Safety Strategy 2010-2020, has a vision to provide a safe road system increasingly free of death and serious injury. It adopts a Safe System approach to road safety focused on creating safe roads, safe speeds, safe vehicles and safe road use (MoT, 2010).

The Safe System philosophy is based on creating a forgiving road system that acknowledges that people make mistakes and have limited ability to withstand crash forces without being killed or seriously injured. Under the Safe System, all parts of the system - roads and roadsides, speeds, vehicles, and road use, all need to be improved and strengthened - so that if one part fails, other parts will still protect people involved in a crash.

Safer Journeys signifies a shift in focus, from reducing crashes to minimising the likelihood of high-severity crash outcomes. In order to give effect to this change in focus, new analytical approaches have been developed that prioritise intersections on the likelihood of future fatal and serious casualty occurrence and risk.

THE HIGH-RISK INTERSECTIONS GUIDE

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.

The High-Risk Intersections Guide introduces a new technique for identifying intersections that have a disproportionally higher than average risk of future deaths or serious injuries if recent crash trends continue. The new technique calculates an estimated number of Death and Serious injury (DSi) casualty equivalents based on relationships between speed environment, intersection form and control type and crash movement type factors. This approach incorporates knowledge that crash outcomes vary as a function of speed, intersection form and control type, and crash movement type. 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.

The High-Risk Intersections Guide provides DSi factors, referred to as Severity Indices, for all primary crash movement types for the following intersection types:

- Signalised crossroads
- Signalised T-intersections
- Roundabouts
- Priority (Give Way or Stop) controlled crossroads
- Priority (Give Way or Stop) controlled T-intersections

Different severity indices are provided for urban (≤70km/h) and rural (≥80km/h) speed environments. The severity indices in the High-Risk Intersections Guide are calculated based on nationwide crash statistics from 2008 to 2012 and represent the average number of deaths and serious injuries per reported injury crash for a specific intersection form, control type and speed environment.

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 estimated 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

Collective Risk is calculated by multiplying each reported injury crash at an intersection over the past five years by the corresponding severity index and summing the values. The Collective Risk of an intersection is then categorised into a five-tiered risk threshold classification. The thresholds have been determined by analysing the safety performance of many thousand existing intersections in New Zealand, and set so that Medium-High and High Collective Risk intersections together make up approximately 5% of all intersections in New Zealand.

The Collective Risk thresholds based on the estimated DSi casualty equivalent approach are set out in Table 1.

Table 1

Criteria for Identifying Intersection Collective Risk

Risk Category	Collective Risk Thresholds (estimated DSi casualty equivalents)
Low	<0.3
Low Medium	0.3 - <0.6
Medium	0.6 - <1.1
Medium High	1.1 - <1.6

Risk Category	Collective Risk Thresholds (estimated DSi casualty equivalents)
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).

Collective Risk is the primary risk metric used for prioritising intersections for road safety countermeasures, as high-risk sites are locations that have the greatest potential for reduction in road trauma.

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 Personal Risk is calculated from the Collective Risk divided by a measure of traffic volume exposure. Intersections with the highest risk per motor 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 flows on each leg of the intersection (Product of Flow).

The Product of Flow formula (PoF) is:

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

- Q_{major} 1 and 2 = the two-way link volume (AADT) on each leg of the major road.
- Q_{minor} 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.

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:

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

The Personal Risk thresholds based on the estimated DSi casualty equivalent approach are 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

Risk Category	Personal Risk Thresholds (estimated DSi casualty equivalents)
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).

Personal Risk is the most relevant risk metric for communicating road safety issues with the public, as risk is defined at an individual level.

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

Level of Service	**Safety (LoSS)**	**Safety**	**Performance**	**Definition**
LoSS I		0-30th percentile		The observed injury crash rate is lower (better) than that expected of 30% of similar intersections.
LoSS II		30th-50th 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		50th-70th 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		70th-90th percentile		The observed injury crash rate is in the worst 30%, lower (better) than that expected of 90% of similar intersections, and higher (worse) than that of 70%.
LoSS V		90th-100th percentile		The observed injury crash rate is in the worst 10 percent band - higher (worse) than that expected of 90% of similar intersections.

The LoSS bands are not separated in even quantiles because many intersections have zero observed crashes.

Intersections where the actual injury crash performance is substantially worse 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 possible for some intersections to have high Collective or Personal risk metrics while the actual injury crash performance is better than the predicted injury crash performance (e.g. LoSS I or II). Intersections with this risk profile are likely to require safe system transformation countermeasures to deliver safety improvements, such as changing the intersection form. For instance, a priority rural crossroad with LoSS III 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 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.

CALCULATING INTERSECTION RISK METRICS FOR A CITY OR REGION

Calculating the Collective and Personal risk metrics, and the LoSS indicator for an intersection requires the following information:

- Crash history;
- Speed environment;
- Intersection form and control type; and
- Traffic link volumes (on all legs of the intersection).

The first three pieces of information are required to calculate Collective Risk, as application of severity indices to the crash history is a function of intersection form and control type as well as the speed environment in which the intersection is located. Personal Risk requires knowledge of the number of vehicles travelling through an intersection on a per leg basis. No further intersection specific information is required to calculate the LoSS indicator.

Crash history is obtained from the NZTA Crash Analysis System (CAS) while other information is typically collected by a Road Controlling Authority and stored in a Road Assessment and Maintenance Management (RAMM) database or equivalent system.

Given the information requirements are readily accessible; it is a relatively straightforward process to calculate the risk profile of any one intersection. With a sound understanding of the assessment techniques in the High-Risk Intersections Guide, in the author’s experience it takes around 30 minutes to source information and manually calculate both risk metrics and the LoSS indicator for an intersection that has more than one reported injury crash.

In isolation this is not a time consuming exercise. However, calculating the risk profile of every intersection within a town, city or region quickly becomes impracticable. In Auckland for instance where there are around 20,000 intersections, the estimated timeframe to manually calculate the risk profile of all intersections would take an individual around 5 working years to complete. By that time, the crash history used in the analysis would be significantly out-of-date, and inappropriate for using as the basis for information where intersection safety interventions are most needed and likely to yield greatest benefit. This shows it is neither economic nor time-efficient to manually calculate the risk profile of every intersection in a large transport network.

Making a Network-Wide Intersection Study Economic and Efficient

Abley Transportation Consultants has developed a Geographical Information Systems (GIS) process that makes calculating the risk profile of all intersections in a town, city or region highly cost-effective and time-efficient compared to the manual equivalent. This has been achieved by utilising transport and road safety information collected by Road Controlling Authorities in combination with analytical skills to identify and prioritise high-risk intersections.

Transport data by its very nature is spatially referenced i.e. relative to a particular point or length of the transport network. For this reason, different sets of transport data can be brought together inside a geospatial environment and used for a variety of purposes, such as calculating the risk profile of every intersection within a transport network.

The GIS process involves running complex algorithms over a fully connected road centreline dataset, which includes speed limit and traffic volume attributes for every part of the network. Intersection form and control type are either included as part of the base centreline network from Road Controlling Authority data or populated based on intersection information extracted from CAS.

Following completion of the base road centreline network, crashes are assigned to the road centreline network based on their geocoded location. Models are then run to identify those crashes located within 50m of an intersection. Complex models are then run which extract the crash movement types of injury crashes at each intersection before the corresponding severity indices are applied for the intersection type. The sum of the DSi casualty equivalents for each crash are then added together to give the overall DSi casualty equivalent value for the intersection, which is known as the Collective Risk.

Models are then run which derive the Personal Risk value from the Collective Risk value by extracting traffic flows on all legs of the intersection and calculating the PoF. The PoF is then inserted into the Personal Risk calculation formula.

GIS enables the risk profile of each and every intersection in a network to be assessed in a standardised and equitable manner. In larger urban areas, it is simply uneconomical and inefficient to carry out a network-wide high-risk intersection assessment without the use of GIS.

ROBUSTNESS OF DSI CASUALTY EQUIVALENTS AS A PREDICTOR OF FUTURE HIGH SEVERITY CRASHES

The advantages of the GIS process are not simply confined to the cost side of the equation. The real advantages are realised on the benefit side of the equation, which is demonstrated through Figure 1.

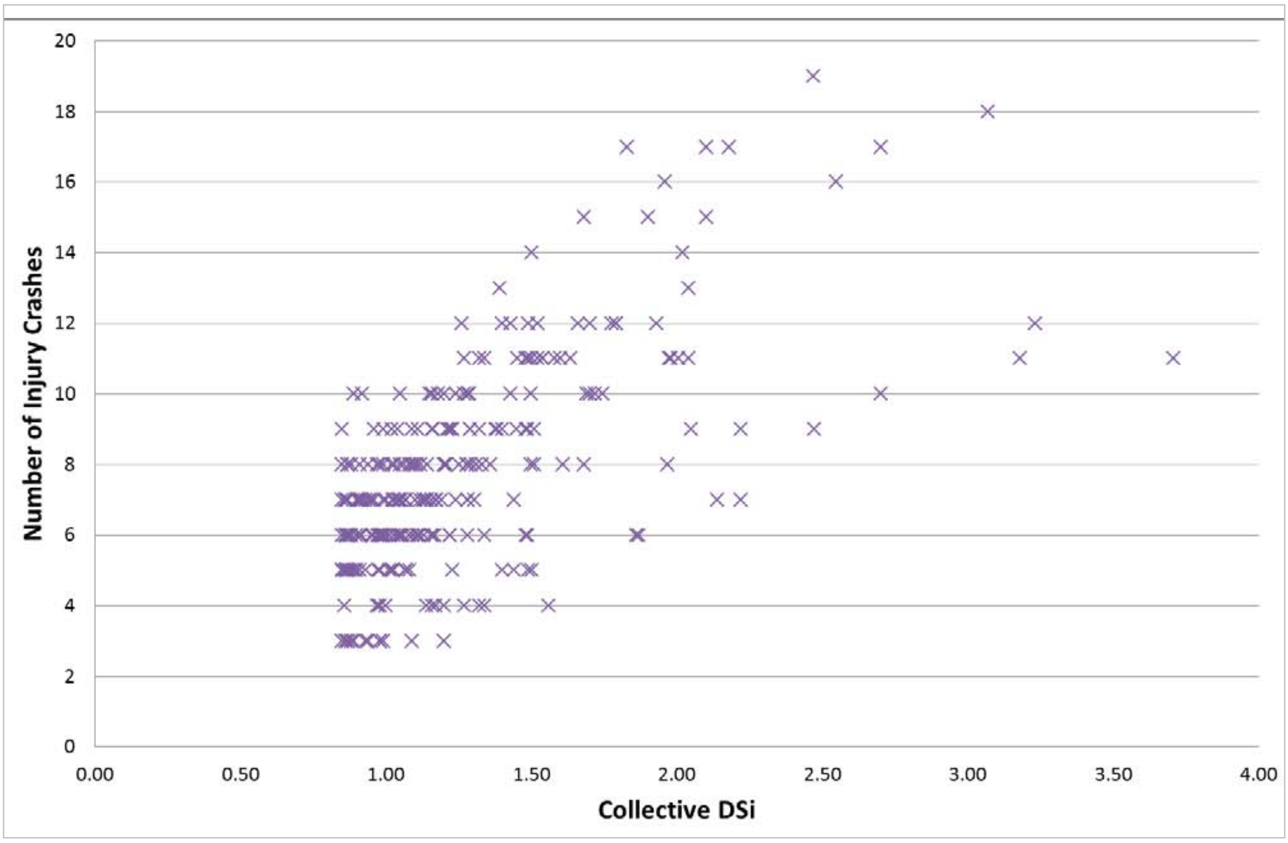

Figure 1

Comparison of Injury Crashes and Collective DSi at Medium to High Risk Intersections

Figure 1 shows the relationship between the number of injury crashes and the corresponding Collective Risk value (based on DSi casualty equivalents) for all intersections in Auckland that have a calculated Collective Risk of Medium and above. It shows that Collective Risk generally increases as injury crash numbers increase.

Under the traditional approach to road safety, it is likely that those with the greatest number of observed injury crashes (those with the largest y-axis values) would be prioritised ahead of others. The approach promoted by the High-Risk Intersections Guide however prioritises those intersections with the highest Collective Risk (those with the largest x-axis values).

Undoubtedly there is some overlap between the two approaches. However, Figure 1 identifies that only 4 intersections with the largest number of injury crashes would be ranked in the top 10 by Collective Risk.

The site classified as the highest-risk intersection in Auckland based on the DSi Collective Risk metric approach was a priority controlled crossroads in a high speed environment and had a crash history of two serious injury crashes and ten minor injury crashes in the five year analysis period. Prior to completion of the risk profiling of the Auckland network, the intersection had previously been identified by the Road Controlling Authority as an intersection with safety issues, however it was not considered a high-priority intersection for treatment, and improvements were ultimately deferred as budgets tightened.

Within weeks of the risk profiling being completed, there were two separate high-severity crashes at the intersection which resulted in the deaths of two people. These unfortunate crashes at the intersection, which were of the same crash movement type that provided the high DSi value, provide an indication of the robustness of the DSi methodology. This suggests that lives can be saved by following the assessment techniques described in the High-Risk Intersections Guide and prioritising intersections for investigation and improvement based on the risk of DSi crashes occurring in the future.

Road controlling authorities put great effort and expense into collecting large quantities of high-quality transport related data. However, the true value of this data is often unrealised because of the narrow range of applications for which the data is used. The network-wide risk profiling process provides a demonstration of the value that can be added to a road controlling authority's activities.

New Zealand's 100 Highest-Risk Intersections

In March 2014, the NZ Transport Agency published a list of New Zealand's 100 highest-risk intersections. The list was produced as an identified action of the Safer Journeys Action Plan 2013-2015 (MoT, 2013). The identification of the 100 highest-risk intersections, the development of solutions for 30 intersections by September 2014 and improvement of 20 intersections by June 2015 were key actions identified in the Safer Journeys Action Plan (MoT, 2013) under the 'Safe Roads and Roadsides' pillar of the safe system approach to road safety in New Zealand.

The list of intersections was compiled using the DSi casualty equivalents method set out in the High-Risk Intersections Guide (NZTA, 2013). A 10-year crash history (2003 – 2012) was used to inform the analysis with double the weighting of crashes being assigned to crashes in the most recent 5-year period.

In May 2014, the list of the Top 100 highest-risk intersections in New Zealand was updated based on 2004 – 2013 crash statistics. As part of this update, the fatal and serious crashes that occurred in 2013 were compared against the DSi risk estimates of the previous Top 100 intersection list to measure the robustness of the DSi casualty equivalents methods as a predictor of future high severity crashes.

The analysis showed that 30 fatal and serious crashes occurred at intersections in the Top 100 highest-risk intersections. By way of context, in 2013 there were 590 fatal and serious crashes at intersections in New Zealand. This translates to 5% of all fatal and serious intersection crashes in 2013 occurring at the 100 highest-risk intersections, just 0.1% of all intersections in New Zealand[1].

Of further interest is that 21 of the 30 fatal and serious intersection crashes occurred at 63% of intersections that did not meet the definition of a high-risk intersection based on actual fatal and serious crash thresholds specified in the High-Risk Intersections Guide (NZTA, 2013). Whilst it is premature to make claims about the effectiveness of an indicator using a limited sample of 'after' data, these early results indicate the DSi casualty equivalent method of assessing risk at intersections appears to be a sound predictor of the likely incidence of future fatal and serious crashes.

CONCLUSIONS

The DSi casualty equivalents indicator provides an estimate of the number of future deaths or serious injuries if recent crash trends continue. The indicator has been developed to give effect to Safer Journeys shift in focus from reducing crashes to minimising the likelihood of high-severity crash outcomes. Analysis of recent fatal and serious crashes at high-risk intersections indicates the DSi approach appears to be a sound predictor of the likely incidence of future fatal and serious crashes.

[1] Estimate of 100,000 intersections in New Zealand based off intersection risk profiling in Auckland, Tauranga, Christchurch and Dunedin completed as part of the Urban KiwiRAP risk mapping project.

Under traditional approaches to road safety many intersections that actually pose high-risk may have been overlooked, because their overall crash history may not have been considered sufficiently high to warrant investigation. Prioritising intersections for investigation and improvement based on the DSi casualty equivalent approach to risk suggests that more lives can be saved in the future.

The key to identifying high-risk intersections is to undertake analysis at a network-wide level. As transport data is spatially referenced, GIS can be used to calculate the risk profile of each and every intersection in a network in a standardised and equitable manner. In larger urban areas, it is simply uneconomical and inefficient to carry out a network-wide high-risk intersection assessment without the use of GIS.

Road controlling authorities put great effort and expense into collecting large quantities of high-quality transport related data. However, the true value of this data is often unrealised because of the narrow range of applications for which the data is used. The network-wide risk profiling process provides a demonstration of the value that can be added to a road controlling authority's activities.

REFERENCES

AASHTO. (2010). *Highway Safety Manual. American Association of State Highway and Transportation Officials*

Cockrem P., Hughes T, and Durdin P. (2013) Intersection Transformation and the Level of Safety Service Indicator. *IPENZ Transportation Group Annual Conference, 14-16 April 2013,* Dunedin, New Zealand.

Durdin, P. (2010). *Christchurch City Council Intersection Safety Intervention Prioritisation Study*

Kononov, J., & Allery, B. (2003). *Level of Service of Safety: Conceptual Blueprint and Analytical Framework. Transportation Research Record, 1840, 57-66*.

Ministry of Transport (MoT). (2010). *Safer Journeys New Zealand's Road Safety Strategy 2010-2020*.

Ministry of Transport (MoT). (2013). *Safer Journeys Action Plan 2013-2015.*

New Zealand Transport Agency (NZTA). (2010) *Economic evaluation manual*

New Zealand Transport Agency (NZTA). (2013). *High-Risk Intersections Guide.*