INTERSECTIONS -

DETERMINING THE GOOD, THE BAD AND THE UGLY

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ABSTRACT

Improving the safety of the road network is a key priority for the New Zealand Government and local road controlling authorities. Intersections are one of the key areas where road safety improvements can offer the best return for investment.

This paper describes how Geographic Information Systems (GIS) was used to directly apply the High-Risk Intersection Guide assessment processes to nearly 15,000 intersections across the Auckland region. All non-State Highway intersections were evaluated based on their safety performance within the period of 1 July 2006 to 30 June 2011. The purpose of this study was to identify intersections that would be classified as 'high-risk' where road safety improvements would be most successful in preventing Death and Serious Injury (DSi) crashes.

The spatial analysis undertaken included the development of a GIS model which included an innovative methodology for assigning crash history to intersections. The results of the analysis were the categorisation of individual intersections based on Personal Risk, Collective Risk and a new indicator, 'Level of Safety Service'.

By using GIS, it was feasible to assess and compare intersections across an entire region, a task previously impractical to conduct at such large scales. The methodology presented in this paper has the potential to be a powerful tool for assisting road controlling authorities to prioritise intersections where improvements in road safety performance are most achievable, and allocate funding for intersection improvements accordingly.

Note: The figures shown within this report have been produced in colour.

INTRODUCTION

This paper outlines the evaluation of the safety performance of all non-State Highway intersections across the Auckland Region within the period of 1 July 2006 and 30 June 2011. The majority of the analysis was undertaken through a Geographical Information System (GIS), which allowed the data to be efficiently analysed in its spatial form.

The purpose of this study was to identify those intersections that would be classified as 'high-risk' as defined in the 'High-Risk Intersections Guide' (referred to as "The Guide" herein) published for consultation by the New Zealand Transport Agency (NZTA) in 2012. By identifying those intersections classified as 'high-risk', road safety investigations and investment can be targeted at those intersections where improvements in road safety performance are most likely to be achievable.

BACKGROUND

According to the Ministry of Transport (2010), despite substantial progress in the past few decades, road safety in New Zealand is still a long way behind other OECD countries. As the number of users of New Zealand's road network continues to grow there is increasing pressure to improve the conditions for the end user and bring us more into line with countries achieving superior safety records.

A strategy for improving the safety of the road network in New Zealand has been published by the Government. The vision set out in Safer Journeys, New Zealand's Road Safety Strategy 2010-2020 (2010), is to improve safety on New Zealand's varied road network by creating and managing "a safe road system, increasingly free of death and serious injury".

The Guide has been prepared by the NZTA to provide guidance on the Government's Safer Journeys 2020 Strategy (2010) initiative to focus efforts on high-risk intersections. The objective of The Guide is to provide practitioners with best practice guidance to identify, target and address key road safety issues at high-risk intersections.

The Guide represents a departure from the traditional approach of treating crash sites in New Zealand, which has generally been to focus efforts on reducing crash occurrence at sites with the greatest number of observed crashes. Road controlling authorities throughout New Zealand are now commonly experiencing diminishing safety benefits when treating crash locations. The Guide endeavours to target intersections that are likely to result in fatal and serious injury crashes as opposed to minor injury or non-injury crashes. It also adopts a partly proactive approach of estimating potential Death and Serious Injury (DSi) crashes based on all injury crashes.

Over the past 10 years, a number of products and techniques have been developed for improving road safety. One of these techniques is the development of crash prediction models for intersections. Crash prediction models take various physical road network features and traffic volumes into account to arrive at a predicted level of crash occurrence.

Focussing road safety efforts at intersections is important as many crashes occur at intersections, especially in urban areas. Research conducted for the NZTA shows that intersection type and traffic flows have a significant influence on the number of crashes that can be expected to occur at any intersection. Some of this research is now incorporated as a road safety assessment technique in the NZTA's Economic Evaluation Manual (2010). Intersections with higher traffic flows generally have a higher crash rate than a similarly configured intersection with lower traffic flows. However, the relationship between traffic flow and crash rate is not linear and varies by intersection type.

A focus on treating intersections with a high crash observation alone can be fruitless if the crash history is similar to or better than would be predicted based on crash prediction models. A different approach, which is more likely to yield road safety benefits, is to compare crash history against predicted crash performance and to prioritise intersections for investigation and treatment where the observed crash history exceeds the predicted crash performance. This analytical approach is known as a Level of Safety Service assessment. It provides an assessment of the intersection performance against predicted performance and is particularly using for prioritising intersections that have the same Collective and Personal Risk profiles. Further details of the Level of Safety Service approach are provided in the 'Risk Metrics' section of this paper.

Intersections that perform poorly against predicted performance will often have inherent flaws that can readily be identified. However, in many instances these intersections may not be investigated because their overall crash history is not considered sufficiently high to warrant investigation. The result is a lost opportunity to improve road safety.

Safer Journeys (2010) identifies that "improving intersections through engineering schemes can aid a reduction in serious accidents." The purpose of this study; to evaluate the safety performance of intersections and identify those classified as 'high-risk' so road safety investigations and investment can be targeted at those sites where road safety improvements are most likely to yield the greatest road safety benefits, is consistent with this statement.

What is a high-risk intersection?

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 2012).

High-risk intersections are broadly defined by the NZTA (2012) as those intersections that have a history of DSi crashes or minor injury crashes that suggest a disproportionally higher than normal risk that someone will be killed or seriously injured in the future. 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.

Under a Safe System approach, set out by the Ministry of Transport (2010), it is appropriate to focus on the number of DSi crashes. However, as very few intersections in New Zealand have multiple (three or more) fatal or serious crashes in a five year period, it can be risky to form safety conclusions about these sites based on a small number of potentially random observations.

The Guide introduces a means of estimating the risk of DSi crashes occurring in the future. It does this by combining knowledge of the inter-relationship between speed environment, intersection type and crash movement type factors. These relationships are presented as Severity Index tables in The Guide. The Severity Indices represent the number of DSi crashes that occur for every injury crash observation for each crash movement type at a particular intersection form and control in either an urban or rural speed environment.

The Severity Index tables 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. 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.

Knowing the composition of crash movement types at any intersection means we can estimate the risk of DSi crashes occurring in the future.

RISK METRICS

The Guide defines two types of risk metric: Collective Risk and Personal Risk.

- Collective Risk, also known as Crash Density, is measured as the number of DSi crashes per intersection in the crash period.
- Personal Risk or Crash Rate is measured in terms of the number of DSi crashes per 100 million vehicles using an intersection.

Collective Risk

There are two methods for defining Collective Risk.

According to the NZTA (2012), the simplest definition of Collective Risk is to consider the number of DSi crashes that have occurred at an intersection in a period of time; normally five or ten years. This definition is referred to as 'Actual DSi Crashes'.

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) (NZTA, 2012).

The second definition involves the prediction of the number of DSi crashes based on all injury crashes that have occurred at an intersection. It involves the multiplication of each injury crash at an intersection by the corresponding Severity Index ratio. This definition is referred to as 'Estimated DSi Crashes'.

The second definition acknowledges that actual DSi crash data alone may not be a good indicator of the underlying DSi crash risk at many intersections. The Collective Risk levels for Predicted DSi Crashes are displayed in **Table 1**.

Table 1. Criteria for Identifying Intersection Collective Risk

Collective Risk Level	Estimated DSi crashes (5 years) from injury crashes
High	> 1.6
Medium High	1.2 – 1.6
Medium	0.85 – 1.2
Low Medium	0.5 – 0.85
Low	< 0.5

Source: NZTA (2012)

Intersections that are assessed as having a 'Medium High' or 'High' Collective Risk are deemed to be high-risk intersections according to the NZTA (2012).

Personal Risk

Intersections with a 'High' Personal Risk are those that have a high number of DSi crashes for the volume of vehicles using it. The sites with the highest risk per vehicle are ranked as the worst from a Personal Risk perspective.

As with Collective Risk, a key issue is 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 'Actual DSi Crashes' or 'Estimated DSi Crashes'.

The Personal Risk calculation formula is:

$$\text{Personal Risk} = \frac{(\text{The greater of Actual DSi crashes or Estimated DSi crashes}) \times 10^{8}}{\text{Product of Flow }(\text{Qmajor} \times \text{Qminor})^{0.4} \times 5 \text{ years} \times 365 \text{ days}}$$

Because it is essential to have sufficient numbers of crashes to establish an appropriate safety countermeasure, the Personal Risk metric is only calculated for intersections that have four or more recorded injury crashes in the past five years. Sites with three or fewer injury crashes in the past five years are excluded from the Personal Risk calculation.

The Personal Risk profile categorisations are displayed in **Table 2.**

Table 2. Criteria for Identifying Intersection Personal Risk

Personal Risk Level	Risk Metrics
High	> 130
Medium High	100 - 130
Medium	70 – 100
Low Medium	40 – 70
Low	< 40

Source: NZTA (2012)

Intersections that are assessed as having a 'Medium High' or 'High' Personal Risk are deemed to be high-risk intersections according to the NZTA (2012).

Level of Safety Service

The Guide also defines a technique for refining the order in which intersections that have the same risk ratings in terms of Collective Risk and Personal Risk are prioritised. This technique, developed by Abley for the NZTA, is known as the Level of Safety Service (LoSS) (Cockrem et al 2013).

The LoSS method is derived from the general flow crash prediction models contained within the NZTA's EEM (2010). Conveniently, LoSS calculations do not require any additional information from that used to calculate Personal Risk scores.

The LoSS method takes into account the speed environment, intersection form and amount of traffic travelling through an intersection. Intersections that have the greatest differential between actual crash performance and predicted crash performance (as defined by the crash prediction models) can be used to indicate the likely potential for crash reduction at sites where the crash history exceeds the modelled crash prediction.

The injury crash performance of an intersection is separated into five LoSS bands, as shown in The Guide.

ANALYSIS

Geographic Information Systems (GIS) was used to directly apply The Guide assessment processes to nearly 15,000 intersections across the Auckland region. Without GIS, the cost of manually calculating the risk metrics of every intersection in the Auckland Region would be very time consuming and cost prohibitive.

GIS was used for the study because it enabled large quantities of data from different sources and in different forms to be analysed through a series of modelling processes. It also provided the platform for bringing information into one location that would allow analysis to be readily rerun when input datasets are updated, such as crash data or traffic volumes, thus minimising future costs. These features made GIS both an efficient and highly cost-effective tool for the study, with each intersection being analysed for less than $4.

Spatial Data

The spatial data used for this analysis included:

- Road centreline data sourced from the Road Assessment and Maintenance Management (RAMM) software system with:
  - traffic flow
  - speed environment
  - names of approaches
- Intersection data created from the road centreline data with:
  - number of approaches
  - intersection control type
- Crash data extracted from the Crash Analysis System (CAS)
  - All injury crashes within the five year period from 1 July 2006 and 30 June 2011.

Methodology

As previously outlined, the minimum level of information required to generate Collective Risk, Personal Risk and Level of Safety Service calculations for an intersection are:

- traffic volumes (on all legs of the intersection);
- speed environment;
- number of approaches;
- intersection control type; and
- crash history.

The process used to get meaningful outputs from the available inputs is shown in **Figure 1**.

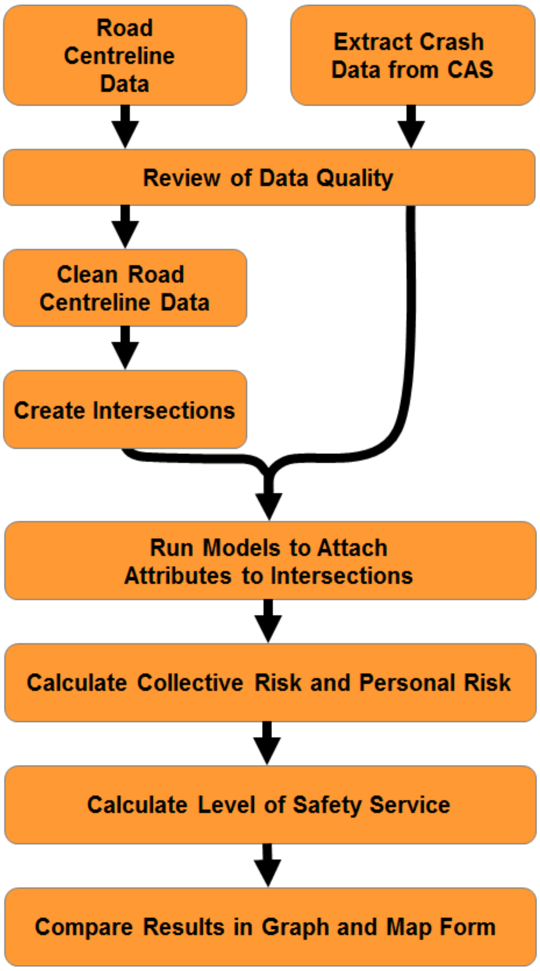

Figure 1. Analysis Flowchart

Assignment of Crashes to Intersections

The Guide defines an intersection crash as "any crash occurring within a 50 metre radius from the centre of an intersection." However this definition was not strictly followed in this study, as there are instances within the Auckland Region, and indeed most urban areas, where intersections are spaced less than one hundred metres apart.

Assigning any one crash to all intersections located within 50 metres of the crash will result in some crashes being assigned to more than one intersection, which may produce misleading outcomes. In order to ensure crashes are not double counted, i.e. each crash is assigned to one intersection only, a methodology has been developed that assigns crashes to the intersection they are most likely to be associated with. In some circumstances this may not always be the closest intersection, as explained in the following two step process:

1. Generate an ordered list of all intersections to be assessed in the study area. For this study, intersections were ordered by adding together the two-way traffic flows on each leg of the intersection (summation of flows). The intersection with the highest summation of flows is ranked highest.
2. Starting at the highest ranked intersection first (from Step 1); assign crashes occurring within 50 metres of that intersection, which occur on a leg of the intersection, to that intersection. Once a crash is assigned to an intersection it is no longer able to be assigned to another intersection. Complete this process for all intersections.

A graphical explanation of how crashes are assigned to intersections is shown in **Figure 2**.

The green Intersection A has the highest combined traffic flow. Crashes within a 50m radius, as shown by the green circle, on Roads 1 and 2 are assigned to this intersection. There is also a crash on Road 3 within its 50m radius, however this crash is not on a road that intersects Intersection A, so it is not assigned to it.

Intersection B, in purple, has the second highest combined traffic flow. Crashes within 50 metres are assigned to this intersection, however there are crashes to the right of the orange Intersection C on Road 1, which are technically within 50 metres of Intersection B. These are not assigned to Intersection B because they occur on a road link that doesn't intersect it.

Intersection D, in red, has the lowest combined traffic flow. All crashes on Roads 3 and 4 within 50 metres are assigned to Intersection D, except the crash that has already been assigned to Intersection B, in purple.

Crashes that are not within 50 metres of any intersection are not assigned to an intersection.

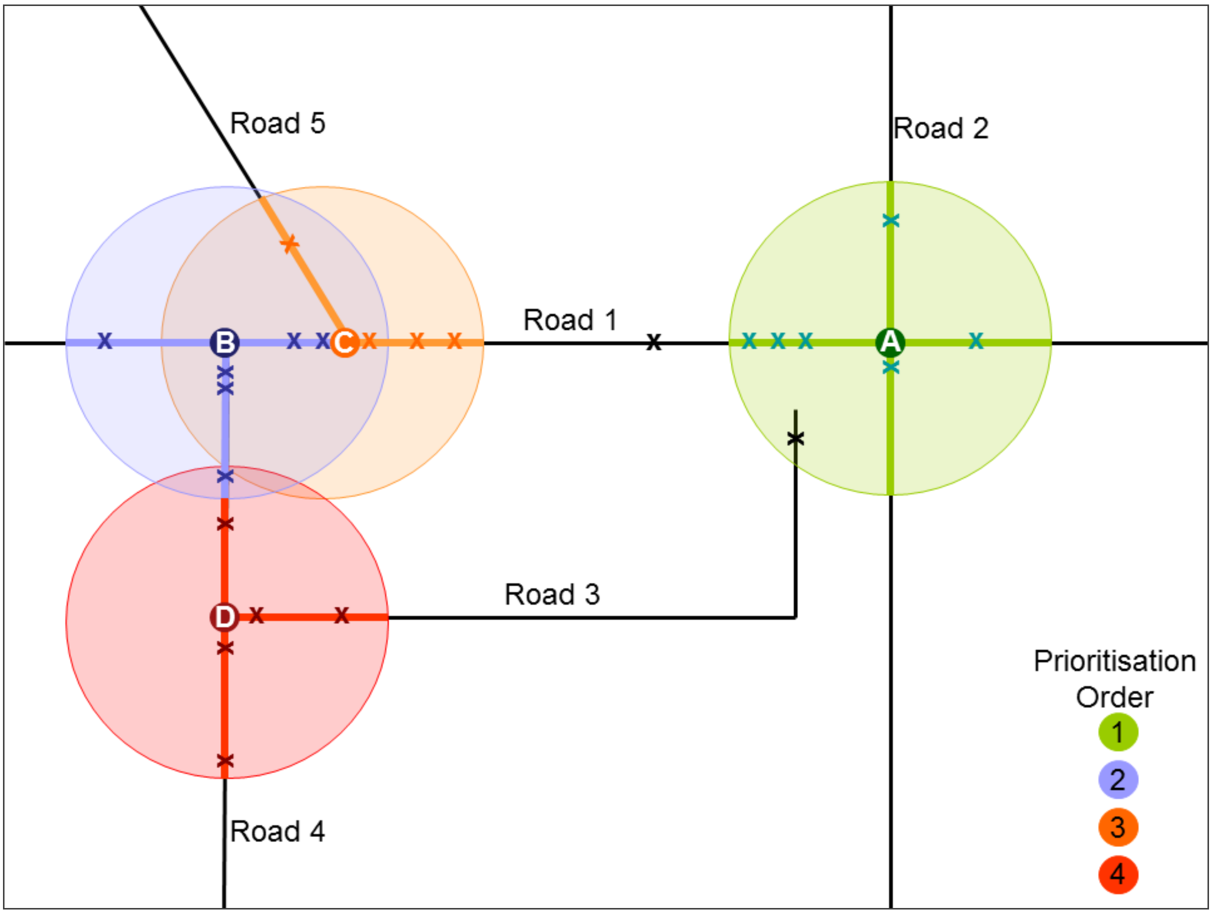

Figure 2. Example of Crash Assignment to Intersections

Note: Crashes are denoted as '**X**' in this figure.

STUDY OUTPUTS

The risk metrics of each intersection in the study area were displayed spatially in map books. Intersections within these map books are colour coded according to their Collective Risk, Personal Risk, and LoSS risk profile. An example of these outputs can be seen in **Figure 3**.

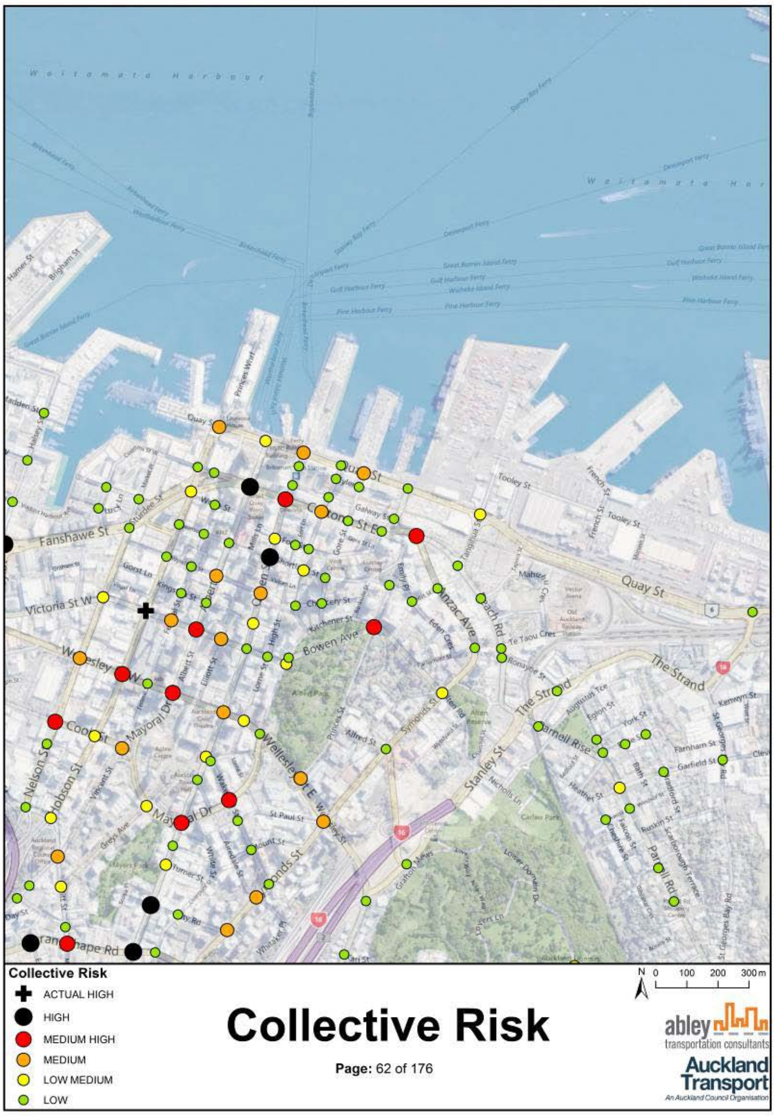

Figure 3. Example Spatial Output

The consideration of the results in a spatial format allows for the identification of clusters of high-risk intersections and provides a strong basis for developing mass action treatments, such as treatments along a corridor.

Distribution of Risk

The risk profile of all intersections in the study area is shown in **Figure 4**. The majority of intersections analysed in this study fall into the lower left quadrant, which indicates intersections with a good safety performance.

Intersections in the upper right quadrant have both a high Collective Risk and high Personal Risk profile meaning they have both a high number of actual or estimated DSi crashes and a high rate of those crashes in comparison to the number of vehicles travelling through the intersection.

The LoSS of each intersection is also displayed in Figure 4. The LoSS analysis shows that many of these low risk intersections perform poorly when compared to other intersections with similar attributes. Nevertheless the overall risk of a crash that results in death or serious injury at one of these intersections remains low.

The LoSS rating gives an indication of how achievable a reduction in injury crashes is likely to be. When prioritising intersections for safety investigation and intervention, the LoSS measure should be used as an indication of how much benefit is likely to result from treating a particular intersection.

Figure 4 shows that the majority of intersections in the upper right quadrant are LoSS V and therefore have a much higher number of observed injury crashes than are predicted for the same type of intersection with similar traffic volumes. Other quadrants in Figure 4 contain a wider mix of LoSS values.

High priority LoSS V intersections generally indicate that large safety gains can be achieved as the intersection is performing poorly in terms of crash history relative to other intersections with similar characteristics.

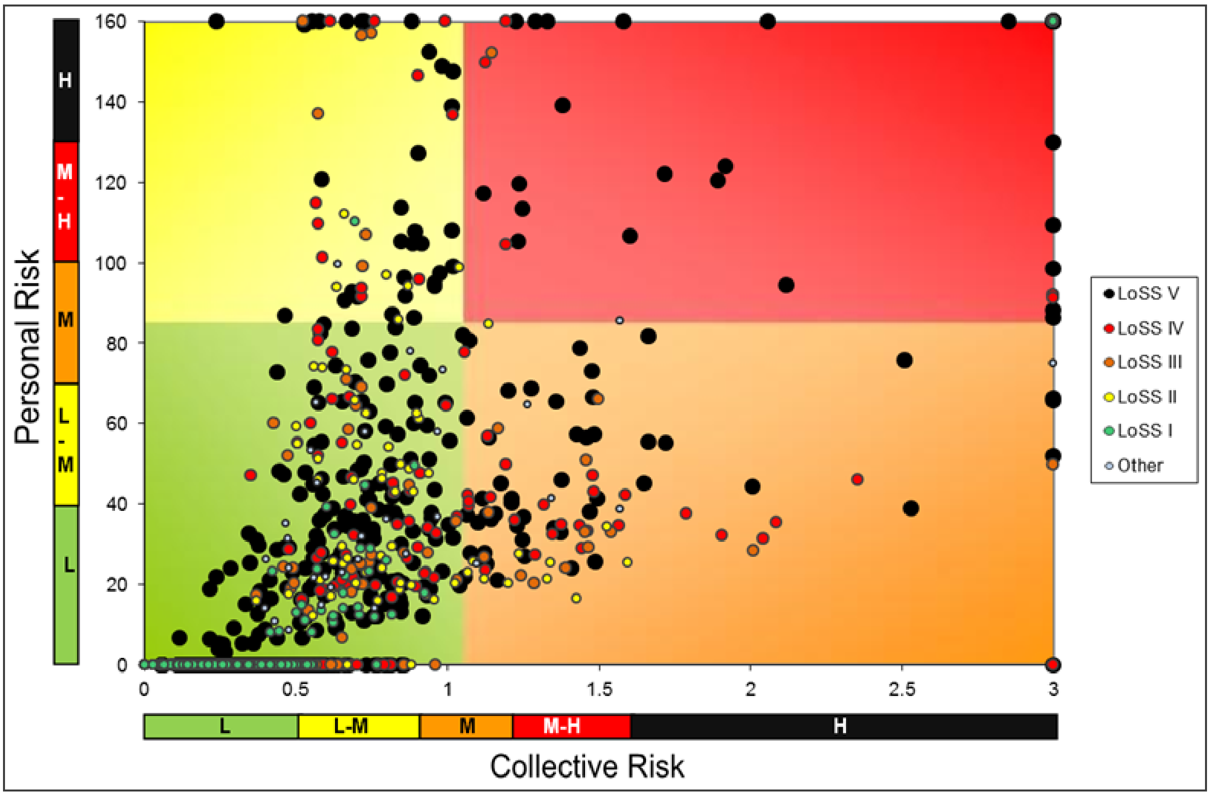

Figure 4. Distribution of DSi Crash Risk and LoSS

A prioritised list of intersections for investigation and intervention was developed from the risk profiles. Auckland Transport is using this list to focus road safety improvement efforts on intersections that have a high-risk profile and those intersections where safety improvements are likely to yield the greatest benefits.

Study Limitations

As with any macro-level study, there are limitations associated with the analysis. The following limitations have been identified as being relevant to this study:

- Some crashes occurring within 50 metres of an intersection may result from non-intersection features on the road network, including but not limited to matters such as curvilinear road geometry leading to loss of control crashes, crashes involving vehicle movements to/from access points, or pedestrians crossing away from intersections.

- The study has not excluded those intersections that have been subject to a recent road safety improvement. This can lead to the situation where an intersection that has been subject to a recent road safety improvement may still be classified as high-risk by this study e.g. where crashes prior to the upgrade still fall within the five year analysis period.
- At closely spaced intersections, crashes are assigned to the intersection with the highest summation of traffic flows. The rationale behind this is that intersections that experience higher flows have higher exposure rates and are therefore more likely to have more crashes. This may result in some crashes being assigned to the wrong intersection.
- The accuracy of the results reflects the accuracy of the input data. Any inaccuracies are likely to result in intersections being analysed incorrectly as part of this study.

Despite these limitations, the outcomes are entirely fit for the study purpose, which was to develop a method for identifying intersections that are classified as 'high-risk' where road safety improvements would be most successful in preventing death and serious injury crashes.

CONCLUSION

This study has evaluated the safety performance of all non-State Highway intersections across the Auckland Region within the period of 1 July 2006 and 30 June 2011. By utilising GIS, the data has been efficiently analysed in its spatial form. This study identified those intersections that would be classified as 'high-risk' as defined in the 'High-Risk Intersections Guide' (2012). By identifying high-risk intersections, road safety investigations and investment can be efficiently targeted at those intersections where improvements in road safety performance are most likely to be achievable.

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