INTERSECTION CRASH COMMONALITIES – AN AUTOMATED PROCESS

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Abstract

There are 455 of intersections in the Auckland region that meet the High Risk Intersections Guide definition of "high risk". The scale of the problem means it is uneconomical, nor practical, to investigate every high risk intersection in detail on an annual basis.

Auckland Transport currently identifies crash commonalities and trends through detailed manual analysis of crash records for selected intersections, with engineering solutions developed to address any identified crash commonalities or causal factors. This is a common industry practice, however a potential shortcoming of this approach relates to the effectiveness of how sites are selected. Site selection is currently based upon whether they meet the High Risk Intersections guide for "high risk"; however, intersections classified as high risk will not necessarily have crash commonalities or causal factors. Therefore, a crash reduction study may determine that engineering solutions alone are unlikely to significantly improve the safety of the intersection.

This paper details the automated assessment tool which was developed to analyse high risk intersections in Auckland for crash commonalities and trends. The outputs from this analysis are shown in a web viewer that identifies crash commonalities and causal factors automatically. This tool is an effective way to identify the intersections that may benefit from more detailed assessment. This allows road safety investment to be targeted at intersections that have the greatest potential for reducing road safety trauma. This tool can also help Auckland Transport select intersections for themed investigations/improvements, such as red-light running or loss of control crashes in wet conditions.

This paper will be of particular interest for those responsible for developing road safety investigation programmes.

1. INTRODUCTION

1.1 Strategic Context

Safer Journeys[1] is the Government's strategy for improving road safety between 2010 and 2020. The strategy's vision is a safe road system increasingly free of death and serious injury.

The Safer Journeys action plans identify intersections as one of the areas of high concern[2] where the highest risk crash types occur[3]. The High Risk Intersections Guide (HRIG)[4] notes that "*During 2008–2012, 30% of all deaths and serious injuries on NZ roads were at intersections. 17% of all deaths and serious injuries on rural roads were at intersections and 46% of all urban deaths and serious injuries were at intersections".* Therefore, high risk intersections are likely to be one of the areas where the greatest reduction in death and serious injuries (DSis) can be achieved.

1.2 Identifying High Risk Intersections

Improvements at high risk intersections can therefore result in a significant reduction in the number of people killed or seriously injured on roads in New Zealand. How these intersections are appropriately identified is the key challenge.

Historically, unsafe intersections were identified based on the number of reported injury crashes recorded in a 5 year period. However, as this methodology does not differentiate between the severity of injury crashes, analysis using this methodology tended to identify high risk intersections as those with a large number of minor injuries. This is because there are significantly more minor injury crashes on the network than there are serious injury or fatal crashes.

In order to effectively address the number of people killed or seriously injured on roads in New Zealand, the definition of high risk needs to reflect the severity of crashes. The HRIG defines high risk intersections as "*intersections with a higher than normal risk that people will die or be seriously injured in the future*" (NZ Transport Agency, 2013).

One method that incorporates crash severity is to determine the social cost of crashes at an intersection. However, this has the opposite effect to the injury crashes methodology as it ends up placing excessive focus on recent fatal crashes. Analysis of crash data showed that 79% of fatal and serious crashes at intersections in Auckland occurred at sites with no previous fatal or serious crashes in the previous 5 years. Furthermore, 64% occurred on sites with 2 or fewer injury crashes on the site in the same period. Therefore, prioritising on fatal and serious crashes alone is not a strong indicator of the risk of high-severity crashes occurring at the site in the future.

The current best practice methodology is to use DSi equivalent values to adjust historical injury crash data. The DSi equivalent values are based on the likelihood of a particular crash type resulting in a death or serious injury. This results in a predictive element to the historical crash data. The process for this is outlined in the HRIG (NZ Transport Agency, 2013). In this methodology, the total DSi equivalents for an intersection over a five year period is used to ascertain the collective and personal risk at the intersection. Collective risk is the total number of DSis equivalents at the intersection during the crash period and personal risk is the risk of

[1] Ministry of Transport *Safer Journeys: New Zealand's Road Safety Strategy 2010-2020*, 2010
[2] Safer Journeys, *Safer Journeys Action Plan (2011-2012)*, 2011, pg. 8
[3] Safer Journeys, *Safer Journeys Action Plan (2013-2015)*, 2013, pg. 16
[4] NZ Transport Agency, *High Risk Intersections Guide*, 2013

death and serious injury to each vehicle entering the intersection (NZ Transport Agency, 2013). A classification of "high" or "medium-high" risk in either category is then used to define a high risk intersection.

1.3 The issue

The Urban KiwiRAP programme applied the DSi equivalents methodology outlined in Section 1.2 to the intersections in Auckland. Based on the calculated collective and personal risk, a total of 455 intersections were identified as high risk. These intersections amount to 2.7% of the intersections in Auckland but account for 33% of all injury crashes and 32% of all fatal and serious crashes at intersections in the region.

However, Auckland Transport (AT) does not currently have the resources to investigate the crash risk for all the identified high risk intersections. The current AT process relies on a detailed manual analysis of crash records to identify crash commonalities and trends at an intersection. AT have also indicated that such an investigation does not necessarily yield commonalities. This most commonly occurs when an intersection has several high severity crashes which are attributed to unrelated crash factors.

AT determined that in order to efficiently improve the safety of their high risk intersections, they would need an effective way to identify which of their high risk intersections would benefit from further investigation. An automated process of reviewing crash records to identify crash factors that are over-represented at an intersection would prove an effective tool for this. In addition to this, having the over-represented factor(s) displayed graphically on a map would help inform themed programme of works, particularly for low cost intersection treatments.

1.4 Automated Process

An automated process that can identify whether a crash factor is over-represented at an intersection was determined to be the most appropriate. Geographical Information Systems (GIS) was identified as the best software to perform the analysis as it would allow the methodology to be applied to the entire region efficiently. GIS also allows the results to be published on a web map that can be accessed by AT staff.

2 Data Source

This process utilises data obtained from the New Zealand Transport Agencies Crash Analysis System (CAS). Crashes that occurred within 50m of an intersection located in the Auckland region were extracted from CAS over the 5 year period of 2011-2014.

3 Crash Factors

3.1 Factors

The first step in the process was selecting which factors, in the CAS data set, the methodology would consider when identifying crash factor commonalities. The crash factors selected for this project were:

- Crash movements;
- Surface conditions – specifically 'wet';
- Time of day;
- Light conditions – specifically 'twilight' and 'dark';
- Red light running;
- Crashes involving pedestrians;
- Crashes involving cyclists; and
- Crashes involving motorcyclists.

Crash movements are described is CAS as a two letter code that identifies the principal movements of the vehicles / users involved in the crash. The first letter identifies the primary crash movement type e.g. B = 'Head On' and the second letter provides further detail on the crash movement type e.g. C = 'Swinging Wide'. For the purposes of this project, crash movements were grouped by the primary crash movement type to align with the process defined in the High Risk Intersections Guide for calculating DSi casualty equivalents. However, due to the similarity of some of the crash movement categories from a safety perspective and to increase the statistical robustness of the analysis, the following primary crash movement categories were merged:

- Movement C (lost control) + Movement D (cornering)
- Movement F (rear end) + Movement G (turning versus same direction)
- Movement N (pedestrian crossing road) + Movement P (pedestrian other)

Movement C+D crashes are collectively defined as "loss of control", Movement F+G crashes as "rear end / turning vs. same direction" and Movement N+P crashes as "pedestrian".

A summary of the crash movements, the corresponding CAS column name and value as well as the icon used to display when the commonality is identified can be seen in **Figure 1.**

Icon	Description	CAS column	CAS value
	Overtaking and lane change	MOVEMENT CODE (MVMT)	AA, AB, AC, AD, AE, AF, AG, AO
	Head on		BA, BB, BC, BD, BE, BF, BO
	Loss of control		CA, CB, CC, CO, DA, DB, DC, DO
	Collision with obstruction		EA, EB, EC, ED, EE, EO
	Rear end / turning vs. same direction		FA, FB, FC, FD, FE, FF, FO, GA, GB, GC, GD, GE, GF, GO
	Crossing (no turns)		HA
	Crossing (vehicle turning)		JA, JC, JO
	Merging		KA, KB, KC, KO
	Right turn against		LA, LB, LO
	Manoeuvring		MA, MB, MC, MD, ME, MF, MG, MO
	Pedestrian		NA, NB, NC, ND, NE, NF, NG, NO, PA, PB, PC, PD, PE, PF, PO
	AM Peak	DATE, DAY AND TIME (DD/MM/YYY) (DDD) (HHMM)	Mon-Fri and 600-900
	Inter Peak		Mon-Fri and 900-1600
	PM Peak		Mon-Fri and 1600-1800
	Weekday Night		Mon-Fri and 1800-2359 or 0-600
	Weekend Night		Sat-Sun and 1800-2359 or 0-600
	Weekend Crash		Sat-Sun and 600-1800
	Twilight/Dark	LIGHT	All values starting with 'T' and 'D'
	Wet	WETNESS	W
	Red light running	TRAF CTRL + MVMT	T and HA.
	Cyclist	VEHICLES	Any value where "S" is listed
	Motorcyclist	VEHICLES	Any value where "M" is listed

Figure 1. Crash factor summary table

4 Thresholds

4.1 Threshold principle

The Austroads Guide to Road Safety Part 8: Treatment of Crash Locations introduces the concept of a 'Threshold Method' to assist in the site selection process (Austroads, 2015). In Auckland, the 'Threshold Method' for site selection relates to the Collective and Personal Risk profile of an intersection, as determined using the High-Risk Intersections Guide analytical processes.

For this project, a set of different thresholds were developed to determine whether a site has any crash factor commonalities. It is applied to all intersections in Auckland that meet the High-Risk Intersections Guide definition of "high risk"

For the purposes of this study, the term 'threshold' relates to a limit (expressed as a percentage). If a crash factor exceeds the threshold for the intersection, it is deemed to have a crash factor commonality.

4.2 Threshold Development

4.2.1 Non-movement thresholds

Thresholds were developed using coded crash reports for all intersection crashes in the Auckland region between 2011 and 2015. Thresholds were first developed for all non-movement crash factors e.g. day/time, dark, wet, road user type etc. Thresholds were informed by determining the average proportion of injury crashes attributed each crash factor for each intersection type (based on the intersection form and control type, and the speed environment). An additional 10% was then added to the average proportion to establish a threshold value that would constitute a crash factor being over-represented i.e. well above the average experienced. For simplicity, thresholds developed using the process described above were rounded up to the nearest 5% (meaning thresholds are 10-14% above the average).

Note that this process applies to all non-movement crash factors. A similar process was used to develop thresholds for crash movements, which is detailed in **Section 4.3**.

4.2.2 Movement thresholds

A different approach was taken to develop thresholds for crash movement factors which distinguished between high and low DSi severity crashes as informed by the High Risk Intersections Guide[5]. This enabled side impact collisions for example to be prioritised ahead of rear end collisions for instance. This approach provides consistency with the Safer Journeys vision of focussing on reducing deaths and serious injuries, and not focussing solely on reducing crash frequency (Ministry of Transport, 2010).

DSi severity indices were used to inform the amount the average proportion each crash movement type would be increased by for the setting of thresholds. For crash movements with a high DSi severity index, the threshold was set slightly above the average proportion and for lower DSi severity indices the threshold was set at a larger amount above the average – that way crash movements with lower DSi severity indices would need to be significantly over-represented before they were identified as a commonality.

[5] NZ Transport Agency, *High Risk Intersections Guide*, 2013 pg. 79-85

Note that for the crash movement types that were amalgamated, thresholds were developed using a weighted average of the individual movement.

Urban Intersections

For urban intersections, the average crash movement type proportions were adjusted as follows:

- High risk movements (severity index > 0.20): +5%
- Medium risk movements (0.12 < severity index ≤ 0.20): +10%
- Low risk movements (severity index ≤ 0.12): +20%

Rural Intersections

A similar approach was taken for rural intersections with the only difference being that the adjustment percentages were modified to reflect the higher average indices in rural speed environments. The following adjustments were made:

- High risk movements (severity index ≥ 0.35): +5%
- Medium risk movements (0.20 < severity index < 0.35): +10%
- Low risk movements (severity index ≤ 0.20): +20%

4.3 Threshold Results

The resulting thresholds as developed on **Sections 4** can be seen in **Appendix A.**

5 Additional Criteria

In addition to the thresholds set for each crash factor, only those intersections with at least three reported incidences of a factor were considered to qualify as a commonality to improve the robustness of the assessment methodology. The value of three was selected, as this is the minimum number of observations of an occurrence required before a trend or pattern can be inferred.

6 GIS Process

GIS models were used to apply the process outlined in **Figure 2**. The input for the analysis is the urban KiwiRAP results which includes number of injury crashes for each of the factors. The process in **Figure 2** is repeated for each of the factors identified in **Figure 1** for each of the high risk intersections.

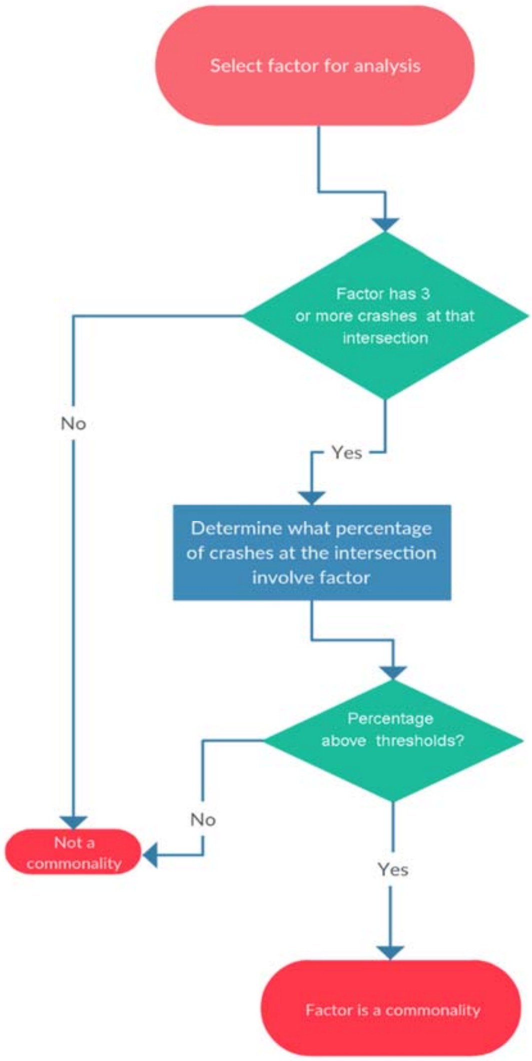

Figure 2. Methodology diagram

7 Results

The results of the analysis have been displayed on a web-map. A screenshot showing an example of the results can be seen in **Figure 3.** Intersections with no icon are either not high risk intersections or they are high risk intersections where no causal factors were identified. The icons on the map correspond to that in **Figure 1.** The icons displayed reflect that the corresponding crash factor is over-represented at that intersection. Note that where the icon is a number, this number indicates the number of commonalities were identified at the intersection. In order to identify what crash factors have been identified at these intersections, a user must hover their mouse over the intersection. **Figure 4** shows the results when a user hovers over the Queen Street / Turner Street intersection.

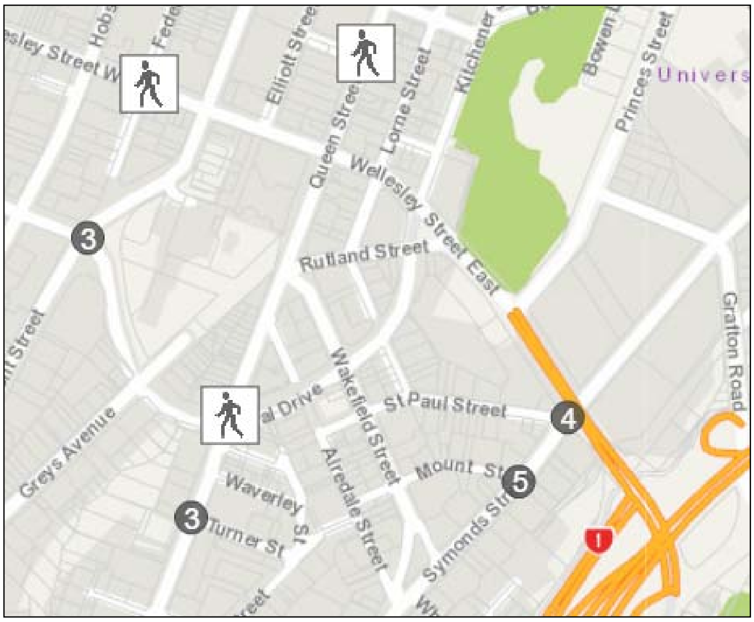

Figure 3. Intersection commonalities results

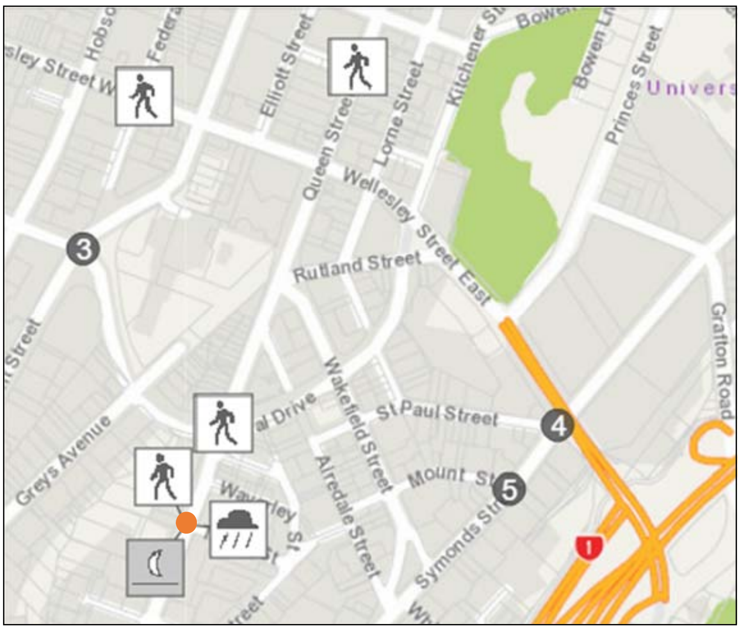

Figure 4. Intersection commonalities results
(showing mouse hovering over Queen St / Turner St Intersection)

8 Application

The results allow AT staff to identify intersections that would benefit from further investigation and to see the crash factor commonalities in the context of the local area. For example, **Figure 3** shows the intersection crash factor commonalities for streets at the southern end of the central business district. It can be seen that pedestrian crashes are over-represented at a number of intersections on Queen Street. Therefore, instead of treating an intersection in isolation, AT could use this information create a programme of works along Queen Street to improve pedestrian safety.

A programme approach can be taken for a number of other factors, particularly where treatments may often be low cost and easy to implement. Other factors and the corresponding treatments which could be used for a programme approach are:

- loss of control crashes (surface treatment to improve skid resistance)
- wet crashes (surface treatment to improve skid resistance)
- twilight / dark (improve street lighting)

9 Conclusion

An automated process was developed using GIS to identify which crash factors were over-represented in accidents at a high risk intersections. To ensure the approach was statistically robust, a minimum of three crashes were specified in order for a crash factor to be considered for further analysis. A threshold approach was then used to determine whether the crash factor was a commonality at the intersection. The threshold values were influenced by the ‘expected’ proportion of crashes for a given crash factor (e.g. Movement B) and intersection type (e.g. signalised T-intersection). When the threshold was exceeded, the crash factor is identified as a commonality for that intersection.

The crash factor commonality results are displayed in a web-map which allows for Auckland Transport staff to quickly identify which intersections will likely benefit from further investigation. The web-map approach enables the results of an area to be mapped so a programme of works may be developed for a series of intersections where the same crash factor commonalities identified.

10 References

AUSTROADS (2015) *Guide to Road Safety Part 8: Treatment of Crash Locations,* Available: https://www.onlinepublications.austroads.com.au/items/AGRS08-15

MINISTRY OF TRANSPORT (2010) *Safer Journeys: New Zealand's Road Safety Strategy 2010-2020*, Available: http://www.saferjourneys.govt.nz/assets/Safer-journeys-files/SaferJourneyStrategy.pdf

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11 Appendix A

Urban Speed Environment

		Causal Factor Thresholds									
Intersection Control Type	**Number of Approaches**	**Wet**	**Light**	**Cyclist**	**Motorcyclist**	**Weekend Night**	**Weekend day**	**Weekday AM Peak**	**Weekday inter-peak**	**Weekday PM Peak**	**Weekday Night**
Priority/Uncontrolled	3 Approaches	35%	40%	25%	30%	20%	25%	30%	35%	25%	30%
	4+ Approaches	40%	40%	20%	25%	20%	30%	30%	40%	30%	30%
Roundabouts	All	35%	45%	30%	30%	25%	30%	25%	40%	20%	35%
Signals	3 Approaches	40%	45%	25%	25%	25%	25%	25%	40%	20%	35%
	4+ Approaches	35%	45%	25%	25%	25%	25%	25%	40%	20%	40%

Intersection Characteristics	Causal Factor Thresholds
Number of Approaches	**Red Light Running**
3 Approaches	35%
4 Approaches	40%

Intersection Characteristics		Movement Factor Thresholds											
Intersection Control Type	**Number of Approaches**	**MVMT A**	**MVMT B**	**MVMT C+D**	**MVMT E**	**MVMT F+G**	**MVMT H**	**MVMT J**	**MVMT K**	**MVMT L**	**MVMT M**	**MVMT N+P**	**MVMT Q**
Priority / Uncontrolled	3 Approaches	5%	10%	25%	25%	35%	10%	25%	10%	25%	15%	20%	5%
	4+ Approaches	5%	10%	15%	25%	20%	40%	20%	15%	20%	15%	15%	5%
Roundabouts	All	20%	15%	25%	20%	40%	35%	15%	25%	20%	20%	15%	5%
Signals	3 Approaches	25%	20%	25%	20%	45%	20%	35%	25%	30%	15%	20%	5%
	4+ Approaches	25%	20%	20%	10%	40%	20%	25%	10%	30%	15%	20%	5%

Rural Speed Environment

Intersection Characteristics		Casual Factor Thresholds									
Intersection Control Type	**Number of Approaches**	**Wet**	**Light**	**Cyclist**	**Motorcyclist**	**Weekend Night**	**Weekend day**	**Weekday AM Peak**	**Weekday inter-peak**	**Weekday PM Peak**	**Weekday Night**
Priority/Uncontrolled	3 Approaches	35%	35%	15%	25%	25%	25%	30%	45%	15%	35%
	4+ Approaches	40%	40%	15%	15%	25%	35%	20%	30%	30%	30%
Roundabouts	All	40%	40%	30%	15%	5%	30%	25%	25%	30%	50%
Signals	3 Approaches	45%	45%	10%	15%	30%	60%	20%	20%	20%	30%
	4+ Approaches	40%	40%	15%	15%	20%	50%	25%	30%	5%	35%

Intersection Characteristics	Causal Factor Thresholds
Number of Approaches	**Red Light Running**
3 Approaches	50%
4 Approaches	60%

		Movement Factor Thresholds											
Intersection Control Type	**Number of Approaches**	**MVMT A**	**MVMT B**	**MVMT C+D**	**MVMT E**	**MVMT F+G**	**MVMT H**	**MVMT J**	**MVMT K**	**MVMT L**	**MVMT M**	**MVMT N+P**	**MVMT Q**
Priority/ Uncontrolled	3 Approaches	10%	10%	40%	10%	55%	5%	15%	10%	10%	10%	5%	5%
	4+ Approaches	10%	10%	25%	10%	40%	35%	15%	15%	15%	10%	5%	5%
Roundabouts	All	25%	25%	25%	25%	45%	60%	25%	25%	25%	20%	10%	10%
Signals	3 Approaches	15%	5%	20%	25%	60%	25%	40%	25%	35%	10%	5%	5%
	4+ Approaches	15%	5%	15%	20%	30%	30%	25%	15%	65%	10%	5%	5%