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Identification of high risk metropolitan intersection sites in Perth, Australia

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ABSTRACT

As convergence points for road users approaching from multiple directions, intersections have more opportunities for conflicts, thus higher crash risk than other parts of the road network. Given the limited resources available for road safety, it is important to identify high risk intersections so that they can be prioritised for infrastructure improvement. This study used a three-stage approach to identify intersections in Perth, Western Australia: using Road Trauma Risk Analysis, then Comparative Safety Performance Analysis and finally ranking the intersections by the KSI (Killed and Serious Injury) metric. These methodologies were developed by Main Roads Western Australia. Crash data from 2011 to 2015 were used in the analyses. The results identify the top high risk intersections for each intersection type (by speed environment and control type). Recommendations are made for extensions to this process to improve identification of high risk intersections, and the use of a taxonomy to identify candidate treatments.

1. Introduction

In 2009, the Government of Western Australia adopted the *Towards Zero* strategy (Office of Road Safety, 2009) which is based on the *Safe System* approach to road safety, combining aspects of Sweden's Vision Zero and the Netherlands' Sustainable Safety approaches (Corben et al., 2010; Langford, 2009). The four cornerstones of the Western Australian Safe System approach are i) *Safe roads and roadsides, ii) Safe speeds, iii) Safe vehicles* and *iv) Safe road use* (Langford, 2009). As part of the strategy, the *WA Safe System Matrix* was created to set identify road safety initiatives in line with the *Safe System* paradigm. In metropolitan Perth, one of these initiatives was the "Safe System intersection transformation" (Langford, 2009). This initiative addresses the higher crash risk at metropolitan intersections, which represent convergence points for all road users.

When analysing crash risk, road safety agencies prioritise the more severe crashes as the trauma associated with such crashes places a heavy burden on society. Risk factors for Killed and Serious Injury (KSI) intersection crashes (compared to crashes involving medical treatment or property damage) in the Perth metropolitan area have previously been identified using crash data from 2006 to 2015 (Chow et al., 2016). Factors associated with significant increased risk of a KSI intersection crash were i) temporal factors (crashes occurring at weekends and at night-time), ii) occurrence at non-level intersections, and iii) three-way, or four or more-way intersections (compared to roundabouts).

This study aimed to use a three-stage approach, using methodologies developed by Main Roads Western Australia, to prioritise intersections which have a higher crash risk for infrastructure improvements. The tools used were Road Trauma Risk Analysis and Comparative Safety Performance Analysis.

2. Materials and methods

A retrospective population-based study was undertaken in the Perth metropolitan area of Western Australia (WA) in Australia. Perth, the capital city of the state of WA, is located on the south-western coast of the state and had a population of approximately 2,039,200 in June 2015 (ABS, 2016).

2.1. Data sources

Crash data (including both police-reported and self-reported crashes) was obtained from the Integrated Road Information System, which is maintained by Main Roads Western Australia, for the period from 1 January 2011–31 December 2015. Intersections on state roads with the Main Roads region code 7 (Perth metropolitan area) which reported at least one casualty (fatal, hospitalisation, or medical treatment) crash were selected for inclusion in the study. This resulted in the inclusion of 996 intersections in the study.

Traffic volume data (annual average daily traffic − AADT) associated

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with each leg of an intersection was obtained from Main Roads Western Australia. If traffic data for 2015 was available, this was used. If traffic data was only available from an earlier year, an annual growth rate of 2.18% was used to estimate the 2015 AADT [the most recent estimate of growth, using the Australian Bureau of Statistics estimates of Million Vehicle Kilometres Travelled – MVKT (ABS, 2015)]. The AADT of all legs were then used to calculate the product of flow which is a single number representation of the intersection's traffic exposure and potential conflict (NZTA, 2013) as follows:

$$Product\ of\ Flow = \left[Average\begin{pmatrix}AADT\ for\ major\ road\\ before\ and\ after\\ intersection\end{pmatrix} \times Average\begin{pmatrix}AADT\ for\ minor\ road\\ before\ and\ after\\ intersection\end{pmatrix}\right]^{0.4}$$

2.2. Intersection type

The selected intersections were grouped by speed environment (three categories) and traffic control type (three categories). *Speed environment* included: i) built-up (all legs of the intersection were less than 80 km/hour and at least one greater than 50 km/hour); ii) open (at least one leg of the intersection was 80 km/hour or more); or iii) low-speed (all legs of the intersection were 50 km/hour or less). *Traffic control type* (Driver Knowledge Test (DKT) Resources, 2017) included: i) traffic signal, ii) roundabout (Road Safety Commission, 2017a), or iii) no traffic signal (Road Safety Commission, 2017b). This created nine possible intersection types: built-up speed environment with traffic signals; built-up speed environment with roundabout; built-up speed environment with no traffic signals; open speed environment with traffic signals; open speed environment with roundabout; open speed environment with no traffic signals; low-speed environment with traffic signals; low-speed environment with roundabout; and low-speed environment with no traffic signals.

2.3. Analysis process

The analysis process of identifying high risk intersections had three steps: Road Trauma Risk Analysis, followed by Comparative Safety Performance Analysis and finally ranking the selected high risk intersections by the KSI metric, a count of killed and serious injury crashes plus factored-up medical treatment crashes. Both Road Trauma Risk Analysis and Comparative Safety Performance Analysis were adapted by Main Roads Western Australia (Main Roads, 2016) building on previous work by the New Zealand Transport Agency (NZTA, 2013).

2.3.1. Road trauma risk analysis

Road Trauma Risk (RTR) for each intersection was assessed using the Road Trauma Risk Analysis. The measure of the horizontal axis of the tool is crash density (the KSI metric) while the measure of the vertical axis is crash rate (the KSI metric divided by the level of exposure to traffic – product of flow). The crash density represents the *collective risk*, or the crash risk experienced by the intersection as a whole in a five year period (2011–2015), while the crash rate represents the *personal risk*, or the crash risk experienced by an individual driver each time he or she drives through that intersection. For each intersection, both crash density and crash rate were rated from low to high (Table 1, based on percentile thresholds obtained from Main Roads Western Australia calculated from 2009 to 2013 crash data). The intersection was then allocated to the correct quadrant (green, orange, red or black) according to the ratings demonstrated in the horizontal axis (crash density) and vertical axis (crash rate) in Fig. 1.

2.3.2. Comparative safety performance analysis

The high risk intersections (those falling in black and, in some cases, red quadrants) were further analysed using the Comparative Safety Performance Analysis. This methodology compared each intersection to other intersections within the same type (similar speed environment and control type) by the KSI metric (Table 2). Each intersection was assigned a percentile score and ranked into a Comparative Safety Performance (CSP) category from I (most safe intersections) to V (least safe intersections). The Comparative Safety Performance Analysis highlights which intersections are performing worse in terms of the KSI metric for their traffic control type, speed environment and product of flow.

Table 1
Thresholds for categories of crash density and crash rate.

Rating	Percentile band	Density	Rate
High	80–100th	Greater than 2.8	Greater than 106.3
Med-High	60–80th	1.4 to 2.7	51.8 to 106.3
Med	40–60th	1.0 to 1.4	29.5 to 51.8
Low-Med	20–40th	1.4 to 0.4	11.4 to 29.5
Low	0–20th	Less than 0.4	Less than 11.4

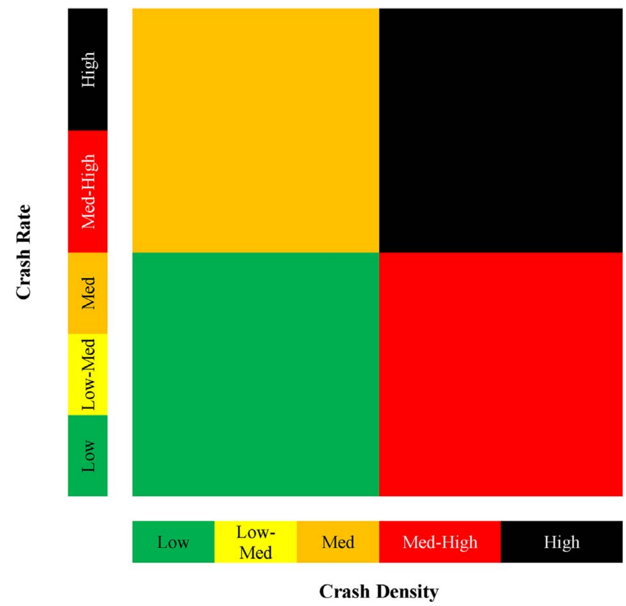

Fig. 1. Road Trauma Risk Analysis tool.

2.3.3. Ranking by KSI metric

Following this, the identified high risk intersections were ranked by the KSI metric. The KSI metric was calculated according to the following equation:

$$KSI\ Metric_{(of\ intersection\ of\ type\ xy)} = \sum_{z}\left[\begin{matrix}No\ of\ KSI\\ Crashes\end{matrix}_{\left(\begin{matrix}of\ crash\ type\\ z\ at\\ intersection\end{matrix}\right)} + Severity\ Index_{xyz} \times \begin{matrix}No\ of\ Medical\\ Crashes\end{matrix}_{\left(\begin{matrix}of\ crash\ type\\ z\ at\\ intersection\end{matrix}\right)}\right]$$

where
x = *speed environment*
y = *intersection control*
z = *crash type*
and

$$Severity\ Index_{xyz} = \frac{Number\ of\ KSI\ Crashes_{xyz}}{Number\ of\ Casualty\ Crashes_{xyz}}$$

Considering that there is always a component of randomness in crashes at any given location, and that a medical treatment crash