The relationship between speed management and projected traffic volumes on major roads along the WA network

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Abstract

Increasing traffic volume has been shown to lead to a differing crash profile on regional roads, which is likely to result in a higher proportion of fatal and serious injuries. This has recently been seen on Indian Ocean Drive, a road following the coast to the north of Perth. Twenty five fatal and serious injury crashes have occurred on this stretch of road during 2012 - 2017 and this is likely the result of a large increase in traffic volume. This study has been undertaken to identify similar high crash risk sections of major routes leading out of Perth for up to 400km, taking into account expected increases in traffic volume over the next ten years. Crash numbers, densities, and rates along sections of these major routes were analysed and potential crashes during 2024-2028 were estimated based on projected historical crash data and projected traffic volume data. The effect of speed limit reductions on these crashes was modelled. A total of 79 high risk road sections were identified based on the top 50 road segments according to the KSI metric density and the KSI metric rate, during the 2014 -2018 period. A further 12 sections of road where an increase in traffic volume may affect the crash profile were also identified. A 10 km/h average speed reduction on the 79 high risk road sections was found to have the potential to reduce the KSI metric by 76 crashes during 2024-2028. A combination of infrastructure improvement and speed management strategies is recommended to prevent serious and fatal injuries on our regional roads.

Keywords

Traffic volume, Speed management, Fatal and serious crashes (KSI)

Disclaimer

This report is disseminated in the interest of information exchange. The views expressed here are those of the authors and not necessarily those of Curtin University or Monash University.

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EXECUTIVE SUMMARY

Introduction

Increasing traffic volume has been shown to lead to a differing crash profile on regional roads, which is likely to result in a higher proportion of fatal and serious injuries. This has recently been seen on Indian Ocean Drive, a road following the coast to the north of Perth. Twenty five fatal and serious injury crashes have occurred on this stretch of road during 2012 - 2017 and this is likely the result of a large increase in traffic volume. This study has been undertaken to identify similar high crash risk sections of major roads radiating out of Perth, taking into account expected increases in traffic volume over the next ten years. The focus was largely on run-off road and head-on crashes as evidence suggests that given a particular road layout and traffic volume, run-off road crashes will migrate to head-on crashes due to the increased likelihood of running into another vehicle, and the crash profile will thus become more severe. Speed reduction strategies are of particular interest, as the size of the WA road network means that infrastructure improvement to safe system standards will not be possible across the whole network in the immediate future. Speed reduction strategies can be applied within a short time frame and are proven to be effective if they have community support and are successfully implemented.

Method

A retrospective population-based study for the five year period from 1 January 2014 to 31 December 2018 in Western Australia was undertaken analysing crash numbers, densities, and rates along 25 kilometre sections of major routes leading out of Perth within a 400 km radius. Potential crashes during 2024-2028 were estimated based on historical crash data and projected traffic volume data. The effect of average speed reductions of 3, 5, and 10 km/h on these crashes was modelled.

Results

A total of 79 high risk road sections were identified based on the top 50 road segments according to the KSI metric density and the KSI metric rate and averaged KSI metric density and rate ranks during the 2014 -2018 period (KSI = fatal and serious injuries). A further 12 sections of road where an increase in traffic volume over the next ten years may affect the crash profile were also identified. The effect of increasing traffic volume on run-off road and head-on crashes were identified. The predicted effect on KSI metric crashes if average speed was reduced by either 3, 5 or 10 km/h was estimated. In most cases, a reduction of 10 km/h will counteract the effect of increases in the KSI metric based on traffic volume increases,

whereas a 3 or 5 km/h decrease would be associated with a net increase in the number of KSI metric crashes.

Reducing the average speed on the combined top 50 high risk road sections by 10 km/h has the potential to reduce the KSI metric by 139 crashes during 2024-2028. A 5 km/h decrease would prevent around 70 KSI metric crashes and a 3 km/h decrease around 42 crashes. However, there is a projected increase of 63 KSI metric crashes as a result of increasing traffic volume.

Discussion

Based on IRIS crash data for 2014-2018 and crash projections for 2024-2028, our analysis identified a number of sections of road with a current or future high risk of fatal and serious injury crashes on major routes leading out of Perth for up to 400 km. The benefits of reducing speed limits on the road sections included in the study were quantified in terms of KSI crashes prevented and the relationship between traffic volume, run-off road and head-on crashes identified.

There are a number of limitations to the study regarding traffic volume, crash projections and the effect of speed management which should be taken into account. These largely relate to availability of detailed data and accuracy of estimates when they are generalised across the road network which was examined in the study. They do not affect the accuracy of current high risk road sections.

Recommendations

i. All current and future high risk road sections should be considered for infrastructure upgrades where this is not currently scheduled.

ii. Posted speed limits should be set based on the infrastructure risk rating. Where the posted speed limit is higher than that recommended as suitable for the infrastructure, it should be reduced to that which is safe for the level of

infrastructure provided. As it is unlikely that large reductions in posted speed limit will be acceptable to the community it is recommended that speed limits are brought down gradually.

iii. Successful reduction of speed limits depends on community acceptance and compliance with this strategy. This will require education and publicity campaigns in tandem with enforcement programs. Community engagement with regards high risk roads should be undertaken throughout the process, as part of infrastructure improvement as well as speed management.

iv. Updating of traffic volume data across the network to a more recent time point would be valuable in improving accuracy crash risk estimates.

v. That infrastructure risk rating and crash prediction be undertaken across the West Australian road network at the small area level incorporating updated traffic volume estimates to improve the identification of current and future high risk road sections and to allow improved estimation of the effect of infrastructure improvement and speed management strategies.

vi. Promotion and adoption of vehicles with technologies such as intelligent speed adaptation, lane deviation warning, lane keep assist, forward collision warning and driver attention assist needs to continue as this will contribute to preventing fatal and serious injury crashes.

1. INTRODUCTION

As a result of a series of 25 fatal and serious injury (KSI) crashes between 1 January 2012 and 21 August 2017 on Indian Ocean Drive between the intersections of Breakwater Drive and Lancelin Road, a safe system review was initiated (Indian Ocean Drive Safety Review Group, 2017). This road, which was originally constructed in the 1970's – 1980's has seen a considerable increase in traffic volumes since the completion of the Lancelin to Cervantes section of the road in 2010. This has led to the increased number of crashes, 28% of which were head-on crashes and 60% run-off road crashes. The investigation found that a number of motorists exceed the posted 110 km/h speed limit along this route leading to an increased risk of loss of control crashes. Lowering of the posted speed limit to 100 km/h was therefore recommended together with a number of infrastructure improvements. These included widening of the sealed shoulder (5.1.2.1), installation of audible tactile edge lines, and installation of a wide centre line treatment with audible tactile centre lines (5.1.3)(Indian Ocean Drive Safety Review Group, 2017). It was proposed that the posted speed limit could be reviewed following completion of the infrastructure treatment.

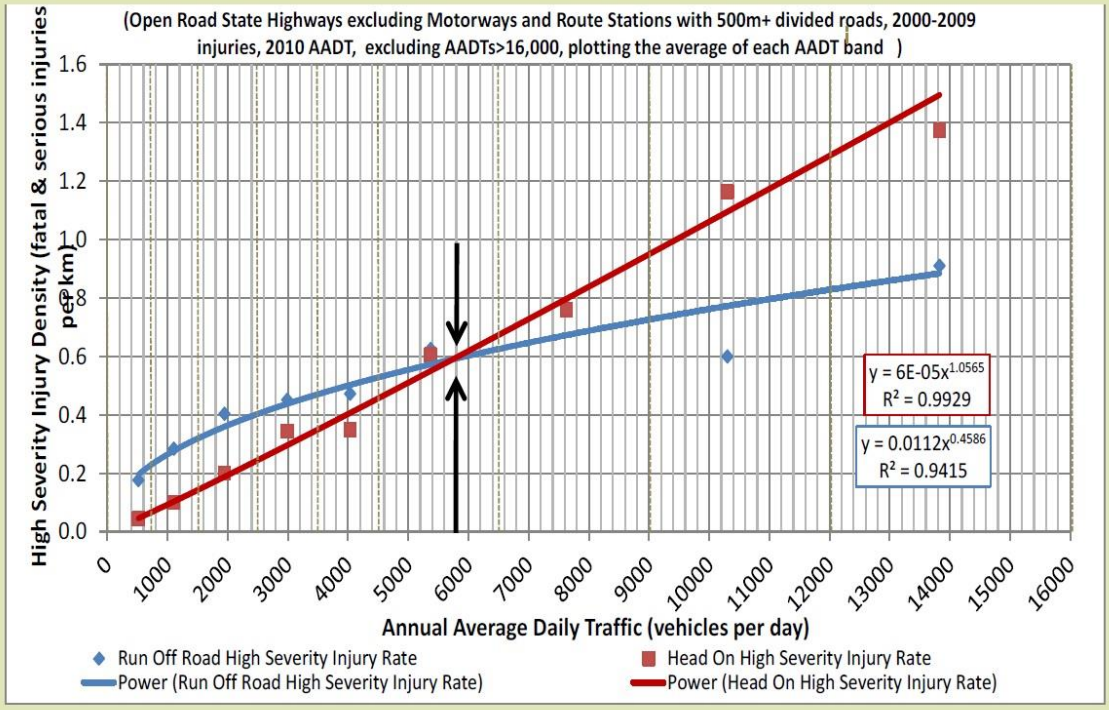
The purpose of this study is to identify other high speed sections of the WA road network within 400 km of Perth where a similar situation could occur and to identify the extent to which this could be ameliorated by reducing the posted speed limit. We have focused on outer metropolitan and regional roads rather than inner metropolitan roads due to the differences in road infrastructure, ie. they tend to be high speed single lane roads with limited protection against oncoming traffic and thus higher severity crashes. There is also a large drop off in traffic volume between inner and outer metropolitan areas. We are particularly interested in run-off road and potential or actual head-on crashes, as they are the major cause of severe injury crashes on high speed regional roads (Austroads, 2015). To ensure good coverage across regional areas within 400 km of Perth, we have included the major routes that allow access into many of the towns within this area.

Single vehicle, loss-of-control run-off road crashes accounted for 57% of fatal crashes and 57% of serious injury crashes during 2014-2018 in the region targeted by our analysis, whereas

head-on crashes were responsible for 25% of fatal crashes and 10% of serious injury crashes. Thus head-on crashes are less common, but when they do occur, are more likely to be fatal. Research from New Zealand shows the rate of KSI run-off road crashes to be higher than the rate of KSI head-on crashes at traffic volumes of up to 6000 vehicles per day on regional roads in New Zealand whereas the rate of head-on crashes is higher once the traffic volume exceeds 6000 vehicles per day (Figure 1-1) (NZ Transport Agency, 2011). When the crash rate is measured per kilometre, the rates of both run-off road and head-on crashes increase with increasing traffic volume. However, if the rates are measure per 100 million vehicle kilometres travelled (100M VKT), thus taking account of the number of vehicles on the road as well as the length of the road, the rate of run-off road crashes declines with increasing traffic volume and the rate of head-on crashes shows a small increase up to around 6000 vehicles per day and then levels off (Figure 1-2). This small increase in head-on crashes is likely to be associated with increased overtaking activity and with run-off road crashes leading to head on crashes when vehicles veer back onto the road (Austroads, 2018; Duivenvoorden, 2010). The decreasing risk of run-off road crashes with increasing traffic volume is likely a result of drivers taking fewer risks in heavier traffic, for example, being less likely to speed. Regional roads with higher traffic volumes may also have increased safety features (NZ Transport Agency, 2011). It is likely that a similar scenario may occur on Western Australian roads and it is important that the traffic volume at which this occurs be identified so that preventative measures can be put in place to prevent increased head-on crashes, as have been seen on Indian Ocean Drive.

Preventative measures to help reduce the risk of run-off road and head-on crashes include improvements to road infrastructure and safer speeds. Run-off road and head-on crashes can be largely prevented by corridor protection (Austroads, 2018). This consists of continuous lengths of barriers down either side of the road and down the middle of the road. Wire rope barriers have been shown to be most effective, followed by w-beams (Chow and Meuleners, 2016). However, cost is prohibitive given the length of Western Australia's road network and alternatives such as wide centrelines with audio tactile lane marking and sealed shoulders with audio-tactile line marking should be considered (Austroads, 2018). Where the density of head-on KSI crashes exceeds that of run-off road KSI crashes, median treatments such as wide

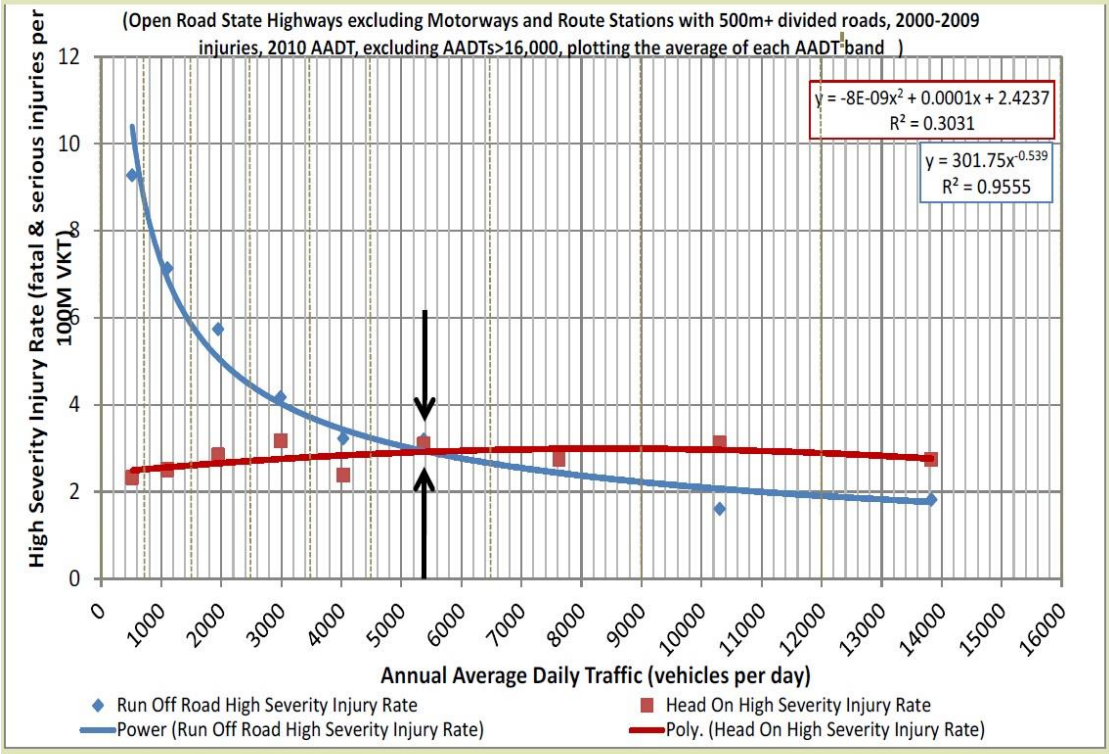
Figure 1-1 Run-off road and head-on injury density



Source: NZTA

Note: Figure 3-6 is based on casualties and is therefore a collective casualty risk.

Figure 1-2 Run-off road and head-on high severity injury rates



Source: NZTA

Note: Figure 3-7 is based on casualties and is therefore a personal casualty risk rate

Source: (NZ Transport Agency, 2011)

centrelines and continuous wire-rope barriers are likely to be more important than roadside treatments (Austroads, 2018; NZ Transport Agency, 2011).

Evidence show that a 1% change in speed is associated with a 2% change in frequency of injury crashes, including a 3% change in frequency of severe crashes and a 4% change in frequency of fatal crashes (Nilsson, 2004; Elvik, 2009). A number of Australian states have successfully demonstrated that lowering of the speed limit has been accompanied by a reduction in casualty crashes. For example, the speed limit on 1100 kilometres of regional and remote roads in South Australia was reduced from 110 km/h to 100 km/h in July 2003. The 10 km/h reduction was accompanied by a 27.4% reduction in casualty crashes during 2003-2013, compared to the baseline period 1993-2003 (Mackenzie et al., 2015). Speed limit reductions were extended to a further 723 km of roads within 100 km of Adelaide and on Yorke Peninsula in 2011. This also appears to be accompanied by reductions in casualty crashes but at the time of the study, insufficient data were available for statistical analysis (Dua et al., 2013). A 26% reduction in casualty crashes was found on the Great Western Highway in NSW following a similar reduction in speed limit (Bhatnagar et al., 2010). Similar reductions in casualty crashes have been reported overseas (De Pauw et al., 2014b; Jaarsma et al., 2011), and increases in crash risk as a result of increases in speed limit have been noted in studies from the USA (Farmer et al., 1999; Souleyrette and Cook, 2010).

For this study we will estimate the effect of potential speed management strategies in reducing the crash risk, using the equations developed by Elvik (Elvik, 2009; Elvik, 2013). Elvik's equations were based on a consolidated database containing the results of 115 studies that present 526 estimates of the effect of a change in speed on crash rates (Elvik, 2009). As evidence suggests that a reduction in posted speed limit of 10 km/h (e.g., from 110km/h to 100 km/h) may reduce average travel speeds by approximately 3-5 km/h we will model the effects that would occur if average speed were reduced by 3km/h and 5 km/h. (Elvik, 2012; Austroads, 2010). We will also look at the potential effect if a decrease in average speed of 10 km/h was achieved – a more ambitious target.

We aim to identify current and future high risk sections of major high speed routes radiating out from the metropolitan area based on current and projected increases in traffic volume.

We will also determine if there is an increasing risk of head-on crashes in comparison to run-off road crashes at a certain traffic volume, on the roads included in the study. We will then estimate the effect of potential speed management strategies in reducing the crash risk.

1.1 Aim

To identify high crash risk sections of major roads radiating out of Perth at present and over the next ten years and to estimate the effect of speed reduction strategies.

1.2 Objectives

1. To identify sections of major high speed routes radiating out from the metropolitan area which currently have a high risk of crashes resulting in serious injury.

2. To identify sections of these routes likely to experience an increasing serious crash profile over the next 10 years based on increased traffic volume.

3. To undertake speed reduction modelling on identified roads to understand the effect of a reduction in the posted speed limit of 10 km/h (eg. from 110km/h to 100km) and a reduction in the average speed of 10km/h on anticipated crashes.

4. To make recommendations with regards to speed management on sections of road identified as having a high crash risk.

1.3 Significance

This project targets the potential reduction of crashes resulting in death and serious injury that may result from implementation of safer speeds on major routes leading out of the Perth outer metropolitan and regional area for a distance of up to 400 km from Perth.

2. METHOD

2.1 Study design

A retrospective population-based study for the five year period from 1 January 2014 to 31 December 2018 in Western Australia was undertaken analysing crash numbers, densities, and rates along sections of major routes leading out of Perth within a 400 km radius. Potential crashes during 2024-2028 were estimated based on projected traffic volume data. The effect of speed limit reductions on these crashes was modelled.

2.2 Data Sources

2.2.1 Crash data

Information about crashes is recorded in the Integrated Road Information System (IRIS), a large dataset of reported crashes (police- and self-reported) in Western Australia which is maintained by Main Roads Western Australia. The database includes information about the time and location of the crash, the nature of the crash and its severity, the units involved (i.e., car, truck, pedestrian, bicycle) and information about the people involved in the crash. The severity of a crash is derived from "*the most serious injury in a crash*". A fatal crash is "*a road crash in which at least one person was killed immediately or died within 30 days of the crash, as a result of the crash"*. A hospitalisation crash is a road crash that involves at least one admission to hospital but *"no fatalities within 30 days of the crash"*. A crash requiring medical treatment is *"a road crash in which the most serious injury resulted in a person requiring medical treatment, but without being admitted to hospital".* A property damage only crash (PDO) involves no or unknown injuries.

For this study we were interested in crashes occurring on specific roads that we identified from a map as being main routes leading out of Perth into regional areas and within a 400 km radius of Perth. The road numbers and names are given in the table 2-1. All sections of the road are included in the study starting from a distance of 50 km from Perth (measured from 31°57'01.9"S and 115°51'37.8"E), and up to 400 km outside of Perth. As we are concentrating on high speed routes, lower speed sections of road leading through towns were excluded based on an exclusion radius around towns proportional to the population of the town (see

Appendix 1). The included roads are all single carriageway other than the entire length of the Forrest Highway and some sections of the Bussell Highway as indicated in Table 2-2.

Table 2-1 Roads included in the study

	COMMON_ROAD_NAME	ROAD_NO
1	Agnew Leinster Rd	M069
2	Agnew Sandstone Rd	M069
3	Albany Hwy	H001
4	Arthur Rd	M037
5	Bannister Marradong Rd	M003
6	Bindoon Moora Rd	M002
7	Borden Bremer Bay Rd	M004
8	Boyanup Picton Rd	M052
9	Brand Hwy	H004
10	Bridgetown Boyup Brook Rd	M006
11	Brockman Hwy	M027
12	Brookton Hwy	H052
13	Brookton-Corrigin Rd	H052
14	Broomehill Gnowangerup Rd	M005
15	Bruce Rock Merredin Rd	M041
16	Bruce Rock Quairading Rd	M041
17	Bullfinch Rd	M040
18	Bussell Hwy	H043
19	Caves Rd	M043
20	Chapman Valley Rd	M064
21	Chester Pass Rd	M001
22	Coalfields Rd	H045

23	Collie Preston Rd	M046
24	Collie Williams Rd	M066
25	Coolgardie Esperance Hwy	H010
26	Corrigin Kondinin Rd	H052
27	Corrigin Kulin Rd	M017
28	Denmark Mt Barker Rd	M014
29	Donnybrook Kojonup Rd	M013
30	Dumbleyung Lake Grace Rd	M037
31	Edward Rd	M054
32	Eyre Hwy	H003
33	Formby Rd South	M015
34	Forrest Hwy	H057
35	George Grey Dr	M058
36	Geraldton Mt Magnet Rd	H050
37	Gnowangerup Jerramungup Rd	M005
38	Goldfields Hwy	H049
39	Goodwood Rd	M042
40	Goomalling Toodyay Rd	M060
41	Goomalling Wyalkatchem Rd	M016
42	Great Eastern Hwy	H005
43	Great Northern Hwy	H006
44	Great Southern Hwy	M010
45	Hopetoun-Ravensthorpe Rd	M059
46	Indian Ocean Dr	M045
47	Katanning Nyabing Rd	M021
48	Kojonup Katanning Rd	M021

49	Kondinin Hyden Rd	H052
50	Kulin Kondinin Rd	M038
51	Kulin Lake Grace Rd	M017
52	Lake Grace Newdegate Rd	M037
53	Leonora Laverton Rd	M022
54	Merredin Nungarin Rd	M016
55	Midlands Rd	M028
56	Mingenew Morawa Rd	M025
57	Mt Magnet Sandstone Rd	M069
58	Muir Hwy	M024
59	Mullewa Wubin Rd	M039
60	Newdegate Ravensthorpe Rd	H052
61	North West Coastal Hwy	H007
62	Northam Pithara Rd	M032
63	Northam Toodyay Rd	M033
64	Northam York Rd	M031
65	Northampton Port Gregory Rd	M058
66	Nungarin Wyalkatchem Rd	M016
67	Nyabing Pingrup Rd	M001
68	Old Coast Rd	M074
69	Pemberton Northcliffe Rd	M036
70	Pingrup Lake Grace Rd	M001
71	Pinjarra Williams Rd	M053
72	Quairading York Rd	M041
73	Railway Av	M016
74	Railway Rd	M061

75	South Coast Hwy	H008
76	South Western Hwy	H009
77	Southern Cross Marvel Loch Rd	M020
78	Stewart Rd	M080
79	Sues Rd	M081
80	Toodyay Rd	M026
81	Vasse Hwy	M008
82	Wagin Dumbleyung Rd	M037
83	Williams Kondinin Rd	H053
84	Wongan Hills Calingiri West Rd	M056

Table 2-2 Bussell Highway single and dual carriageway sections by SLK

Dual Carriageway sections (SLK)	Single Carriageway sections (SLK)
0-26.73	26.73-43.6
43.6-49.02	49.02-51.62
51.62-52.59	52.59-57.69
57.69-59.45	59.45-140.79

2.2.2 Traffic volume data

Data on current and projected traffic volume for these roads was obtained from Main Roads. This included the volume of vehicles at specific locations by traffic year. The projected annual growth in traffic was also provided for each location. The Main Roads growth projections are based on state wide modelling of higher speed routes in outer metro and regional areas. They

are based on a modelling scenario that takes into account future road upgrades and land use data. Land use data includes population by workers and age group, employment data for 15 employment classes and enrolment data for primary, secondary and tertiary education(GHD, 2016). Traffic volume was based on AADT (Annual Average Daily Traffic). AADT does not account for fluctuations in traffic by time of day or time of year. AADT was updated to 2018/19 from the most recent traffic year available using the growth rates provided by the Main Roads model and then projected to 2028/29 based on the same growth rates.

2.3 Identification of high risk road sections

Road maps for WA were obtained from https://data.wa.gov.au/, the WA government data website. Crash, traffic volume, and spatial data were linked in R (version 3.6.0; R Core Team 2019). An exclusion boundary around Perth of 50 km radius was set to remove inner metropolitan high traffic volume roads. Road sections in regional towns were also excluded as these have lower speed limits. The radius of the exclusion zone varied from 1 - 25 km depending on the population size of the town. Roads were segmented into 25 km sections based on true distance positioning. Segments of less than 25 km exist if the study boundary was less than 25km from the previous road segment. The minimum road segment length for the study was set at 12.5km. The metrics shown in Table 2-3 were then calculated for each road segment.

Table 2-3 Metrics for identification of high risk road sections

Metric	Code/Definiton/Formula
All Crashes	Severity codes 1-5
Fatality crashes	Severity code 1
Serious injury crashes	Severity code 2
KSI (fatal and serious injury crashes)	Severity code 1-2
Medical crashes	Severity code 3
Property damage only crashes	Severity codes 4-5
Casualty crashes	Severity codes 1-3
KSI metric	KSI crashes & a proportion of medical crashes
Crash density (Collective risk)	Crashes per km per year

Crash rate (Personal risk)	Crashes per million vehicle km travelled per year
KSI metric density	KSI metric crashes per km per year
KSI metric rate	KSI metric crashes per million vehicle km travelled per year
Estimated speed	Posted speed limit where crash occurred
Head–on crash	Road user movement (RUM) codes 21,51
Run-off road crash	RUM codes 71, 72, 73, 74, 81, 82, 83, 84

Formulas for the KSI metric, crash density and crash rate were as follows. The measures are based on the KSI metric which includes fatal and serious injuries as well as estimate of the more severe medical injuries. This measure is used here so that we do not undercount serious injuries.

The KSI metric was calculated by,

$$KSI_{metric} = KSI + \frac{KSI}{casualty\ crashes} * \ medical\ crashes$$

where KSI is the sum of fatal and serious crashes, and casualty crashes are the sum of fatal, serious, and medical crashes (Main Roads Western Australia, 2018). Crash density (collective risk), is a measure of crashes that occur per km of road per year. It is calculated by taking the average crash count for a period divided by the length of road,

$$Crash\ Density = \frac{total\ crashes/_{5\ years}}{segment\ length}$$

Crash density can be calculated for the KSI metric by,

$$KSI_{metric}Density = \frac{KSI_{metric}/_{5_{years}}}{segment\ length}$$

Crash rate (personal risk), is a measure of crashes that occur per million vehicle km of travel on the road. It is a measure of the likelihood of an individual being involved in a crash on that road,

$$Crash\ Rate = \frac{{total\ crashes}/{5_{years}}}{segment\ length * 365 * AADT} * 10^6$$

As for crash density, crash rate can be calculated for the KSI metric by,

$$KSI_{metric}Rate = \frac{{KSI_{metric}}/{5_{years}}}{segment\ length * 365 * AADT} * 10^6$$

Crash maps were created based on the various measures in R using the "leaflet" (Cheng et al., 2018) and "leaflet.extras" (Karambelkar and Schloerke, 2018) packages. The base map was provided by Wikimedia.

High risk routes were defined as the top 50 road sections (with ≥ 3 KSI crashes over 5 years) according to the KSI metric density, KSI metric rate, and combined rankings of the KSI metric density and rate. Both measures have been used as we wish to identify high risk roads based on both traffic volume per kilometre but also to identify lower volume roads are high risk according to crash density. The combined measure allows both measures to be compared at the same time.

To obtain the top 50 crash sites a threshold of 0.054 for KSI metric density and 0.10 for KSI metric rate was used. To obtain the combined KSI metric rank, the ranks of KSI metric density and KSI metric rate were summed, ranked, and road sections with ranks < 50 were retained. For comparison, a report by the New Zealand Transport Agency (NZ Transport Agency, 2011)(section 4-1, page 25) describes functions for categorising road sections as high, medium-high, medium, low-medium, and low-risk sections of road for KSI density and KSI risk. For a 25 km stretch of road, a high risk road was defined as a section with > 0.12 KSI density or > 0.12 KSI rate. A medium-high risk road is defined as a section with > 0.07 KSI density or > 0.069 KSI rate.

Due to the particular concern about increases in high severity head-on crashes, run-off road and head-on crashes were identified as a proportion of total crashes. This represents an indicator of where the greatest increases of run-off road and head-on crashes may be seen if traffic volume reaches the level at which the more severe head-on crashes are likely to predominate.

2.4 Projected number of crashes for 2024-2028

The projected increase in crashes consistent with traffic volume was calculated based on the relationship between crashes and traffic volume. This was repeated for fatality crashes, serious crashes, medical crashes, KSI metric, head-on crashes, run-off road crashes, and for the KSI metric for run-off road and head-on crashes. Due to the small number of road sections with a segment length less than 25 km (but more than 12.5 km), we also fit each crash metric as a function of crash density to ensure consistency of the relationship. For all measures, the parameters between crash density and straight crash were similar (e.g., total crash β = 0.628, total crash density β = 0.617).

Following testing of various model, non-linear least squares regression was used to model the influence of traffic volume on crash number. A power-law function was fit to volume and crash data of the form,

$$y = \alpha * AADT^{\beta} + \varepsilon$$

where *AADT* is the traffic volume, α and β are the parameters estimated by the non-linear algorithm, and ε the error of the model. This The power function has previously been demonstrated to be a good fit for this relationship (NZ Transport Agency, 2011). Confidence intervals for crash projections from the volume power function were calculated by taking the mean beta coefficient +/- two times the standard error.

Our aim was to generate an approximate projection of future crashes based on the historical trend in crashes and its relationship to traffic volume. We have assumed that geometric features of included roads were reasonably consistent and have not accounted for factors such as road stereotype (eg two-lane undivided, divided with traversable median), horizontal alignment, intersection density, access density, roadside hazards, shoulder width and land use which have been shown to effect crash risk on rural roads (Austroads, 2019).

2.5 Potential reduction in crashes associated with reducing the speed limit.

To model the effect of a reduction in speed limit on crashes, we used the relationship identified by Elvik (Elvik, 2009) that takes the ratio between the new and old speed, raises this

ratio to an empirically derived power exponent and multiplies this outcome by the number of crashes at the existing speed limit, i.e.,

$$Crash_{POST} = \left(\frac{Speed_{POST}}{Speed_{PRE}}\right)^{n} * Crash_{PRE}$$

where *n* = power exponent relevant to crash or injury type. For fatality, serious, and injury crashes, we used the best estimate (±95% CI, to give an approximate indicator or precision) of *n* = 4.1 (95% CI = 2.9, 5.3), 2.6 (95% CI = -2.7, 7.9), and 1.1 (95% CI = 0.0, 2.2) respectively. To assess different speed reduction scenarios, we modelled average speed reductions of 3, 5, and 10 km/h reductions, reflecting the findings from the reviews by Elvik and Jurewicz which suggest that a reduction in posted speed limit of 10 km/h may reduce average travel speeds by approximately 3-5 km/h (Elvik, 2012; Austroads, 2010).

2.6 Ethics Approval

Ethics permission for this study was obtained from Curtin University Human Research Ethics Committee (approval number: HRE2018-0525).

3. RESULTS

The total number of KSI crashes observed on study roads and the total KSI crashes on the top 20 high risk road sections according the KSI metric density, KSI metric rank, and the combined KSI metric density and rate rank broken down by crash type are shown in Table 3-1. There were a total of 868 KSI crashes on the study roads, with run off road and head on crashes accounting for 81% of fatal crashes and 66% of the serious injury crashes. While head on KSI crashes were fewer in number than run off road crashes (115 vs 492), head on crashes were more likely to result in a fatality than run off road crashes. Other crash types accounted for 30% of remaining crashes and 18.2% of fatality crashes. The top 20 high risk road sections (according the combined KSI metric density and rate rank) accounted for 167 KSI crashes (19% of all road sections) and 16% of fatality crashes on the study roads.

Table 3-1 Crashes broken down by major crash types on all roads and the top 20 high risk roads according to each ranking method.

Crash type	Total	Head On	Head On %	Run Off Road	Run Off Road %	Other	Other %
All study roads							
KSI	868	115	13.2	492	56.7	261	30.1
Fatalities	198	50	25.3	112	56.6	36	18.2
Serious	670	65	9.7	380	56.7	230	34.3
Top 20 high risk road sections – combined metric							
KSI	167	31	18.6	86	51.5	50	29.9
Fatalities	31	13	41.9	15	48.4	3	9.7
Serious	136	18	13.2	71	52.2	47	34.6
Top 20 high risk road sections – KSI metric density							
KSI	208	43	20.7	100	48.1	65	31.3
Fatalities	47	18	38.3	22	46.8	7	14.9
Serious	161	25	15.5	78	48.4	58	36.0
Top 20 high risk road sections – KSI metric rate							
KSI	89	14	15.7	59	66.3	16	18.0
Fatalities	22	6	27.3	16	72.7	0	0.0
Serious	67	8	11.9	43	64.2	16	23.9

3.1 High risk crash locations on major arterials within 400 km of Perth

Figure 3-1(A-C) shows the top 20 high risk road segments and Table 3-2 shows the combined top 50 road segments according to the KSI metric density, the KSI metric rate, and averaged KSI metric density and rate ranks during the 2014 -2018 period. Using these criteria, a total of 79 high risk road sections were identified. The identified sections include 250 km (10 sections) of the South Western Highway outside of the metropolitan area from Pinjarra to Bunbury, 225 km (nine sections) of Albany Highway (from a start point South of Jarrahdale to a start point south of Williams and from a start point south of Kojunup towards Mount Barker) and 175 km (seven sections) of Great Southern Highway (York to Beverley, south of Pingelly and south of Wagin to near Tambellup).

The top 20 high risk road sections selected according to the combined rank of KSI metric density and KSI metric include sections of the following roads (numbers in brackets give the start of the road section in terms of true distance):

- Albany Highway - (53.1 – 78.1) south of Jarrahdale, (128.1 – 153.1) north of Williams and (278.1 – 303.1) south of Kojunup
- Boyanup Picton Road – (1.0 – 26.0) south of Dardanup
- Brockman Highway – (50.0 – 75.0) north of Augusta
- Bussell Highway – (77.6 – 102.6) from Cowaramup southwards
- Caves Road – (26.6 – 51.6) south of Yallingup and (51.6 – 76.6) south of Prevelly
- Great Eastern Highway (57.5 – 82.5) north of Wundowie
- Great Northern Highway (41.5 – 66.5) near Bindoon
- Great Southern Highway (7.1 – 32.1, 32.1 -57.6) west of York
- Indian Ocean Drive – (6.5 – 31.5, 31.5 – 56.5, 56.5 – 81.5) north of Two Rocks to north of Lancelin
- Muir Highway – (25.8 – 75.8) south of Manjimup
- Northam York Road – (2.6 – 27.6) south of Northam
- Pinjarra Williams Road – (25.0 – 50.0) south of Dwellingup
- South Western Highway – (54.1 – 79.1) south of Pinjarra
- Toodyay Road – (13.2 – 38.2) south of Toodyay.

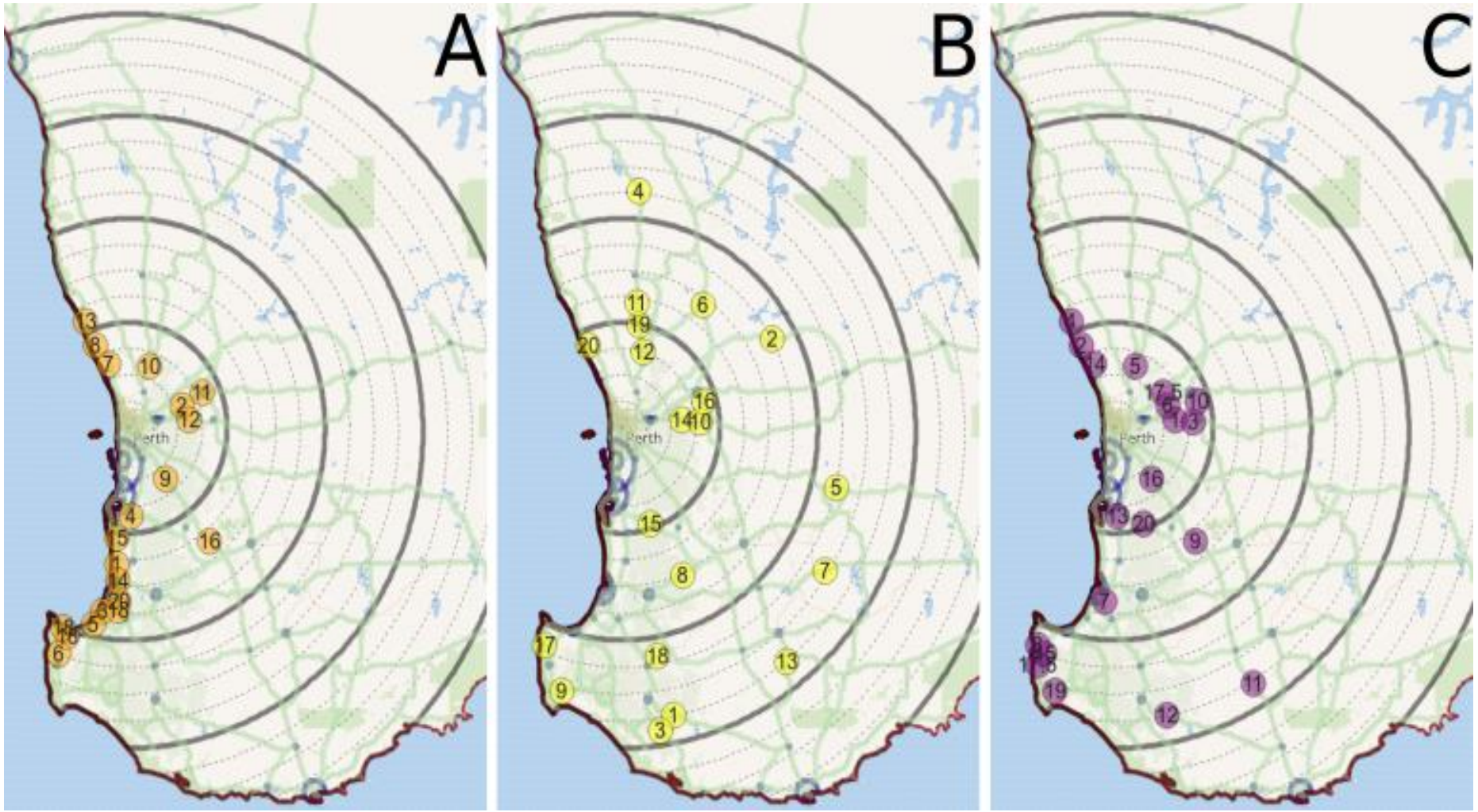


Figure 3-1 Top 20 high risk road sections by KSI metric density (A; orange), KSI metric rate (B; yellow), combined ranking across KSI metric density and rate (C; purple).

To put into the context of Indian Ocean Dr, five sections of Indian Ocean Dr were captured in Table 1. In particular, the three sections of Indian Ocean Dr from Yanchep to Lancelin experienced 136 total crashes over a distance of 75 km (rounded to nearest 25 km), 53 of those involved a fatality or injury (requiring hospital or medical treatment), and the KSI metric was 46.2 for the combined sections. The estimated traffic volume of these stretches of road range from 2612 (nearest to Lancelin) to 5359 (nearest to Two Rocks/Perth). Five crashes involving fatalities occurred between Yanchep and Lancelin. One further fatality occurred further north of Lancelin near Wedge Point, just north of the intersection with Wedge Island Rd. The KSI metric density and rate for the three sections of Indian Ocean Dr closest to Perth ranged from 0.11 – 0.14 (crash density - high risk range) and from 0.07 to 0.13 (crash rate - medium high to high risk range). The combined KSI metric rank of one of these sections of Indian Ocean Dr (around Seabird) was 2 (KSI metric crash density rank = 8, crash rate rank = 20) and another section ranked 4th (around Lancelin; KSI metric density rank = 13, crash rate rank = 24).

The section of road with the highest rank according to the combined KSI metric rate and density ranking occurred on the section of Great Southern Hwy (also known as Chidlow York Rd) beginning from just east of Chidlow and stretching through to just south of York. However, the second site closer to York, while having a KSI metric above 3, only had 1 KSI crash. These two sites were ranked 1 and 3 according to the combined ranking. The sites had a volume of 1891 and 1342. The KSI metric for each site was 13.87 and 6.16. The KSI metric density was 0.111 KSIm/km (rank = 12) and 0.092 KSIm/km (rank = 21). The KSI metric rate was 0.161 KSIm/mvkt (rank = 14) and 0.188 KSIm/mvkt (rank = 10).

The section of road with the highest rank according to the KSI metric density (collective risk) ranking occurred on the section of Forrest Hwy just north of Bunbury. The section has a very high volume of 15406 and a KSI metric of 30.62. The KSI metric density was 0.235 KSIm/km (rank = 1) whereas the KSI metric rate relatively low at 0.044 KSIm/mvkt (rank = 77).

The section of road with the highest rank according to the KSI metric rate (personal risk) ranking occurred on the section of Muir Hwy south east of Manjimup. The section had a very low volume of 365 and a KSI metric of 6.72. The KSI metric density was 0.054 KSIm/km (rank

= 49) and a KSI metric rate of 0.404 KSIm/mvkt (rank = 1). While five serious injury crashes occurred, no fatality crashes occurred on this section.

3.1.1 Run-off road and head-on crashes on high risk road sections

Run-off road and head-on crashes on the high risk road sections are shown in figure 3-5 and described in table 3-3. These form 70% or more of KSI metric crashes on just under half (46%) of the road sections, including a number of sections on Albany Highway, Bindoon Moora Road, Great Southern Highway, Indian Ocean Drive and South Western Highway. The proportion of run-off road and head-on crashes gives an indication of the current potential for migration to head-on crashes.

Table 3-2 Locations ranked in the top 50 by KSI metric density, KSI metric rate, and combined KSI metric density & rate

Road Name	Road #	Start True	End True	Segment Length	Speed	2018 AADT	Total Crashes	Fatality Crashes	KSI metric	KSI metric density (KSI/km)	KSI metric Rate (KSI/mvkt)	KSI metric density rank	KSI metric rate rank	Combined Rank
Albany Hwy	H001	53.1	78.1	25	110.0	4507	41	5	14.7	0.12	0.07	9.0	50.0	16.0
Albany Hwy	H001	78.1	103.1	25	110.0	3949	24	1	8.9	0.07	0.05	32.0	70.0	49.0
Albany Hwy	H001	103.1	128.1	25	110.0	3005	23	1	8.6	0.07	0.06	36.0	56.0	38.0
Albany Hwy	H001	128.1	153.1	25	110.0	2758	27	2	12.6	0.10	0.10	16.0	31.0	9.0
Albany Hwy	H001	153.1	178.1	25	110.0	3618	26	1	9.3	0.07	0.06	27.5	61.0	31.5
Albany Hwy	H001	278.1	303.1	25	110.0	1717	17	0	9.3	0.07	0.12	27.5	21.0	11.0
Albany Hwy	H001	303.1	328.1	25	110.0	1762	21	0	6.6	0.05	0.08	52.0	41.0	39.5
Albany Hwy	H001	353.1	378.1	25	110.0		28	3	8.9	0.07		32.0	95.0	
Albany Hwy	H001	378.1	403.1	25	110.0		22	1	6.9	0.05		47.0	96.0	
Bindoon Moora Rd	M002	0.0	25.0	25	105.0	650	13	2	5.1	0.04	0.17	71.5	12.0	28.0
Bindoon Moora Rd	M002	25.0	50.0	25	100.0	650	6	2	4.0	0.03	0.13	93.5	19.0	62.0
Bindoon Moora Rd	M002	50.0	75.0	25	110.0	650	9	2	5.6	0.04	0.19	62.5	11.0	22.0
Boyanup Picton Rd	M052	1.0	17.6	17	105.0	2320	22	2	7.7	0.09	0.11	20.0	25.0	7.0
Brand Hwy	H004	11.4	36.4	25	110.0	3657	26	1	7.9	0.06	0.05	39.0	72.0	59.5
Brand Hwy	H004	86.4	111.4	25	110.0	1738	16	1	7.1	0.06	0.09	43.5	35.0	25.0
Bridgetown Boyup Brook Rd	M006	1.6	26.6	25	100.0	564	12	0	3.6	0.03	0.14	112.5	18.0	73.0
Brockman Hwy	M027	50.0	73.2	23	100.0	664	16	1	5.7	0.05	0.20	54.0	9.0	19.0
Brookton Hwy	H052	37.8	62.8	25	110.0	1520	17	1	6.1	0.05	0.09	55.5	36.0	37.0
Brookton Hwy	H052	62.8	87.8	25	110.0	1145	11	1	4.1	0.03	0.08	87.5	45.0	74.0
Brookton Hwy	H052	87.8	112.8	25	110.0	1046	13	2	5.6	0.04	0.12	62.5	22.0	30.0
Brookton-Corrigin Rd	H052	185.8	199.7	14	110.0		8	0	4.0	0.06		42.0	99.0	
Bussell Hwy	H043	2.6	27.6	25	110.0	16151	79	4	22.6	0.18	0.03	3.0	88.0	35.5
Bussell Hwy	H043	27.6	52.6	25	110.0	14093	63	3	19.5	0.16	0.03	5.0	89.0	41.5
Bussell Hwy	H043	52.6	77.6	25	110.0	5610	38	1	11.7	0.09	0.05	18.0	75.0	39.5
Bussell Hwy	H043	77.6	102.6	25	110.0	6006	69	2	19.2	0.15	0.07	6.0	51.0	15.0
Bussell Hwy	H043	127.6	141.5	14	110.0	1835	9	0	3.7	0.05	0.08	51.0	43.0	41.5
Caves Rd	M043	1.6	26.6	25	90.0	9984	78	0	11.7	0.09	0.03	18.0	90.0	57.0
Caves Rd	M043	26.6	51.6	25	90.0	1357	39	1	9.2	0.07	0.15	29.0	17.0	8.0
Caves Rd	M043	51.6	76.6	25	85.0	1900	41	0	8.9	0.07	0.10	32.0	29.0	17.5

Road Name	Road #	Start True	End True	Segment Length	Speed	2018 AADT	Total Crashes	Fatality Crashes	KSI metric	KSI metric density (KSI/km)	KSI metric Rate (KSI/mvkt)	KSI metric density rank	KSI metric rate rank	Combined Rank
Coalfields Rd	H045	0.0	25.0	25	100.0		29	2	8.9	0.07		32.0	101.0	
Collie Williams Rd	M066	26.5	51.5	25	110.0	361	7	1	3.6	0.03	0.22	112.5	8.0	66.0
Corrigin Kondinin Rd	H052	226.9	247.8	21	110.0	326	5	2	3.0	0.03	0.24	106.0	5.0	59.5
Dumbleyung Lake Grace Rd	M037	187.9	212.9	25	110.0	390	6	0	4.0	0.03	0.22	93.5	7.0	47.0
Forrest Hwy	H057	0.0	25.0	25	110.0	12305	23	0	7.3	0.06	0.01	40.5	93.0	76.0
Forrest Hwy	H057	25.0	50.0	25	110.0	14512	61	1	13.2	0.11	0.02	15.0	91.0	55.5
Forrest Hwy	H057	50.0	75.0	25	110.0	15406	133	4	30.6	0.24	0.04	1.0	77.0	24.0
Forrest Hwy	H057	75.0	94.3	19	110.0	16361	39	2	10.3	0.11	0.02	14.0	92.0	55.5
Great Eastern Hwy	H005	57.5	82.5	25	110.0	6147	78	4	22.7	0.18	0.08	2.0	42.0	6.0
Great Eastern Hwy	H005	82.5	107.5	25	110.0	5757	35	5	14.3	0.11	0.05	11.0	63.0	23.0
Great Eastern Hwy	H005	282.5	307.5	25	110.0	1552	12	3	5.6	0.04	0.08	62.5	46.0	58.0
Great Northern Hwy	H006	41.5	66.5	25	90.0	3203	43	0	14.6	0.12	0.10	10.0	32.0	5.0
Great Northern Hwy	H006	91.5	116.5	25	110.0	1542	14	2	7.0	0.06	0.10	46.0	33.0	26.0
Great Southern Hwy	M010	7.1	32.1	25	110.0	1891	43	2	13.9	0.11	0.16	12.0	14.0	1.0
Great Southern Hwy	M010	32.1	45.5	13	100.0	1342	23	0	6.2	0.09	0.19	21.0	10.0	3.0
Great Southern Hwy	M031	111.0	136.0	25	110.0	950	7	1	3.6	0.03	0.08	112.5	40.0	85.5
Great Southern Hwy	M031	211.0	236.0	25	110.0	991	10	1	4.7	0.04	0.10	77.5	28.0	53.5
Great Southern Hwy	M031	236.0	261.0	25	110.0	897	10	0	4.7	0.04	0.12	77.5	23.0	47.0
Great Southern Hwy	M031	261.0	286.0	25	110.0	1248	18	1	5.7	0.05	0.10	59.0	30.0	33.0
Great Southern Hwy	M031	286.0	311.0	25	110.0	538	11	2	4.1	0.03	0.17	87.5	13.0	47.0
Indian Ocean Dr	M045	6.5	31.5	25	110.0	5359	57	2	17.6	0.14	0.07	7.0	49.0	14.0
Indian Ocean Dr	M045	31.5	56.5	25	110.0	2501	45	2	15.0	0.12	0.13	8.0	20.0	2.0
Indian Ocean Dr	M045	56.5	81.5	25	110.0	2612	42	1	13.6	0.11	0.11	13.0	24.0	4.0
Indian Ocean Dr	M045	206.5	231.5	25	110.0	1069	13	1	4.1	0.03	0.09	87.5	39.0	71.0
Indian Ocean Dr	M045	231.5	256.5	25	110.0	917	11	0	3.6	0.03	0.09	112.5	38.0	84.0
Midlands Rd	M028	100.0	125.0	25	110.0	321	9	0	3.6	0.03	0.24	112.5	4.0	63.0
Muir Hwy	M024	25.8	50.8	25	100.0	365	11	0	6.7	0.05	0.40	49.0	1.0	12.0
Northam Pithara Rd	M032	78.4	103.4	25	110.0	328	7	2	3.6	0.03	0.24	112.5	6.0	64.0
Northam York Rd	M031	2.6	27.6	25	110.0	1284	22	2	8.9	0.07	0.15	32.0	16.0	10.0
Nungarin Wyalkatchem Rd	M016	56.6	81.6	25	110.0	234	8	0	4.0	0.03	0.37	93.5	2.0	43.0
Pinjarra Williams Rd	M053	0.0	25.0	25	80.0	2021	25	1	6.7	0.05	0.07	49.0	48.0	44.0
Pinjarra Williams Rd	M053	25.0	50.0	25	110.0	955	16	1	6.7	0.05	0.15	49.0	15.0	20.0

Road Name	Road #	Start True	End True	Segment Length	Speed	2018 AADT	Total Crashes	Fatality Crashes	KSI metric	KSI metric density (KSI/km)	KSI metric Rate (KSI/mvkt)	KSI metric density rank	KSI metric rate rank	Combined Rank
Railway Rd	M061	1.9	16.2	14	100.0		8	0	4.0	0.06		45.0	125.0	
South Coast Hwy	H009	447.6	472.6	25	90.0		40	0	11.4	0.09		22.0	127.0	
South Coast Hwy	H009	472.6	497.6	25	110.0		24	0	10.0	0.08		24.5	128.0	
South Western Hwy	H009	29.1	54.1	25	110.0	3902	23	0	7.1	0.06	0.04	43.5	82.0	68.0
South Western Hwy	H009	54.1	79.1	25	110.0	5528	54	4	19.7	0.16	0.08	4.0	47.0	13.0
South Western Hwy	H009	79.1	104.1	25	110.0	3643	39	0	8.4	0.07	0.05	37.0	68.0	51.5
South Western Hwy	H009	104.1	129.1	25	110.0	3653	32	3	9.7	0.08	0.06	26.0	58.0	29.0
South Western Hwy	H009	129.1	154.1	25	80.0	4134	33	2	10.0	0.08	0.05	24.5	64.0	31.5
South Western Hwy	H009	154.1	179.1	25	110.0	7988	40	1	11.7	0.09	0.03	18.0	87.0	51.5
South Western Hwy	H009	179.1	204.1	25	100.0	4260	49	0	11.3	0.09	0.06	23.0	59.0	27.0
South Western Hwy	H009	204.1	229.1	25	100.0	3028	24	3	7.3	0.06	0.05	40.5	65.0	53.5
South Western Hwy	H009	229.1	254.1	25	110.0	2618	24	1	8.1	0.07	0.07	38.0	53.0	35.5
South Western Hwy	H009	304.1	329.1	25	90.0	375	12	0	5.3	0.04	0.31	67.5	3.0	21.0
Sues Rd	M081	0.0	25.0	25	110.0	987	11	1	4.7	0.04	0.10	77.5	27.0	50.0
Toodyay Rd	M026	13.2	38.2	25	90.0	1776	29	0	8.7	0.07	0.11	35.0	26.0	17.5
Vasse Hwy	M008	0.0	25.0	25	110.0	1394	14	0	5.6	0.04	0.09	62.5	37.0	45.0
Vasse Hwy	M008	125.0	150.0	25	95.0	1370	14	0	6.1	0.05	0.10	55.5	34.0	34.0
Williams Kondinin Rd	H053	4.6	29.1	24		1049	10	0	3.7	0.03	0.08	99.0	44.0	79.5

Table 3-3 Run off road and head on crashes 2014-2018 (for road sections as above)

Road Name	Road #	Start True	End True	Seg Length	Speed	2018 AADT	Total Crashes	Total Head On	Total off path	KSI metric	KSI metric Head On	KSI metric offpath	KSI metric % (off path + head on)/total
Albany Hwy	H001	53.1	78.1	25	110.0	4507	41	2	18	14.7	2.0	10.2	83
Albany Hwy	H001	78.1	103.1	25	110.0	3949	24	4	8	8.9	2.0	5.4	84
Albany Hwy	H001	103.1	128.1	25	110.0	3005	23	2	9	8.6	1.0	5.0	70
Albany Hwy	H001	128.1	153.1	25	110.0	2758	27	3	14	12.6	2.8	7.0	78
Albany Hwy	H001	153.1	178.1	25	110.0	3618	26	2	14	9.3	2.0	4.8	73
Albany Hwy	H001	278.1	303.1	25	110.0	1717	17	0	7	9.3	0.0	3.2	35
Albany Hwy	H001	303.1	328.1	25	110.0	1762	21	1	11	6.6	0.0	4.6	70
Albany Hwy	H001	353.1	378.1	25	110.0		28	3	11	8.9	2.0	3.8	66
Albany Hwy	H001	378.1	403.1	25	110.0		22	1	12	6.9	0.8	3.2	58
Bindoon Moora Rd	M002	0.0	25.0	25	105.0	650	13	0	9	5.1	0.0	3.6	70
Bindoon Moora Rd	M002	25.0	50.0	25	100.0	650	6	1	3	4.0	1.0	3.0	100
Bindoon Moora Rd	M002	50.0	75.0	25	110.0	650	9	1	5	5.6	1.0	3.0	72
Boyanup Picton Rd	M052	1.0	17.6	17	105.0	2320	22	2	9	7.7	1.0	3.6	60
Brand Hwy	H004	11.4	36.4	25	110.0	3657	26	2	11	7.9	2.0	4.2	79
Brand Hwy	H004	86.4	111.4	25	110.0	1738	16	4	5	7.1	1.8	4.0	81
Bridgetown Boyup Brook Rd	M006	1.6	26.6	25	100.0	564	12	1	8	3.6	1.0	2.6	100
Brockman Hwy	M027	50.0	73.2	23	100.0	664	16	0	11	5.7	0.0	2.6	46
Brookton Hwy	H052	37.8	62.8	25	110.0	1520	17	1	8	6.1	1.0	4.2	85
Brookton Hwy	H052	62.8	87.8	25	110.0	1145	11	0	8	4.1	0.0	4.2	100
Brookton Hwy	H052	87.8	112.8	25	110.0	1046	13	0	7	5.6	0.0	3.0	54
Brookton-Corrigin Rd	H052	185.8	199.7	14	110.0		8	0	1	4.0	0.0	0.0	0
Bussell Hwy	H043	2.6	27.6	25	110.0	16151	79	3	18	22.6	3.0	9.6	56
Bussell Hwy	H043	27.6	52.6	25	110.0	14093	63	6	16	19.5	5.8	7.0	66
Bussell Hwy	H043	52.6	77.6	25	110.0	5610	38	3	11	11.7	2.0	3.4	46
Bussell Hwy	H043	77.6	102.6	25	110.0	6006	69	7	13	19.2	4.3	6.4	56
Bussell Hwy	H043	127.6	141.5	14	110.0	1835	9	0	2	3.7	0.0	1.6	43
Caves Rd	M043	1.6	26.6	25	90.0	9984	78	1	14	11.7	0.8	5.4	53
Caves Rd	M043	26.6	51.6	25	90.0	1357	39	2	16	9.2	0.0	5.4	59
Caves Rd	M043	51.6	76.6	25	85.0	1900	41	2	12	8.9	2.0	3.8	66
Coalfields Rd	H045	0.0	25.0	25	100.0		29	5	12	8.9	3.5	4.2	87
Collie Williams Rd	M066	26.5	51.5	25	110.0	361	7	0	3	3.6	0.0	1.0	28
Corrigin Kondinin Rd	H052	226.9	247.8	21	110.0	326	5	0	4	3.0	0.0	3.0	100

Road Name	Road #	Start True	End True	Seg Length	Speed	2018 AADT	Total Crashes	Total Head On	Total off path	KSI metric	KSI metric Head On	KSI metric offpath	KSI metric % (off path + head on)/total
Dumbleyung Lake Grace Rd	M037	187.9	212.9	25	110.0	390	6	0	5	4.0	0.0	4.0	100
Forrest Hwy	H057	0.0	25.0	25	110.0	12305	23	0	9	7.3	0.0	4.6	63
Forrest Hwy	H057	25.0	50.0	25	110.0	14512	61	1	24	13.2	1.0	7.6	66
Forrest Hwy	H057	50.0	75.0	25	110.0	15406	133	0	52	30.6	0.0	18.2	60
Forrest Hwy	H057	75.0	94.3	19	110.0	16361	39	1	9	10.3	1.0	3.8	47
Great Eastern Hwy	H005	57.5	82.5	25	110.0	6147	78	7	29	22.7	2.0	9.4	50
Great Eastern Hwy	H005	82.5	107.5	25	110.0	5757	35	2	10	14.3	2.0	4.6	46
Great Eastern Hwy	H005	282.5	307.5	25	110.0	1552	12	1	4	5.6	1.0	2.0	54
Great Northern Hwy	H006	41.5	66.5	25	90.0	3203	43	2	17	14.6	1.0	6.6	52
Great Northern Hwy	H006	91.5	116.5	25	110.0	1542	14	2	5	7.0	1.0	4.0	71
Great Southern Hwy	M010	7.1	32.1	25	110.0	1891	43	6	22	13.9	3.8	9.8	98
Great Southern Hwy	M010	32.1	45.5	13	100.0	1342	23	4	11	6.2	1.0	4.2	85
Great Southern Hwy	M031	111.0	136.0	25	110.0	950	7	0	4	3.6	0.0	2.6	73
Great Southern Hwy	M031	211.0	236.0	25	110.0	991	10	1	6	4.7	1.0	2.8	81
Great Southern Hwy	M031	236.0	261.0	25	110.0	897	10	0	7	4.7	0.0	3.2	68
Great Southern Hwy	M031	261.0	286.0	25	110.0	1248	18	1	9	5.7	0.0	2.6	46
Great Southern Hwy	M031	286.0	311.0	25	110.0	538	11	2	7	4.1	1.0	2.6	87
Indian Ocean Dr	M045	6.5	31.5	25	110.0	5359	57	9	15	17.6	6.5	4.8	64
Indian Ocean Dr	M045	31.5	56.5	25	110.0	2501	45	7	17	15.0	3.8	8.4	81
Indian Ocean Dr	M045	56.5	81.5	25	110.0	2612	42	7	11	13.6	3.0	5.8	65
Indian Ocean Dr	M045	206.5	231.5	25	110.0	1069	13	2	3	4.1	1.0	1.0	48
Indian Ocean Dr	M045	231.5	256.5	25	110.0	917	11	0	8	3.6	0.0	2.6	73
Midlands Rd	M028	100.0	125.0	25	110.0	321	9	0	4	3.6	0.0	2.6	73
Muir Hwy	M024	25.8	50.8	25	100.0	365	11	0	8	6.7	0.0	6.2	92
Northam Pithara Rd	M032	78.4	103.4	25	110.0	328	7	1	5	3.6	1.0	2.6	100
Northam York Rd	M031	2.6	27.6	25	110.0	1284	22	1	11	8.9	0.0	5.8	66
Nungarin Wyalkatchem Rd	M016	56.6	81.6	25	110.0	234	8	1	3	4.0	1.0	2.0	75
Pinjarra Williams Rd	M053	0.0	25.0	25	80.0	2021	25	3	9	6.7	1.8	4.6	95
Pinjarra Williams Rd	M053	25.0	50.0	25	110.0	955	16	1	7	6.7	1.0	2.2	48
Railway Rd	M061	1.9	16.2	14	100.0		8	0	2	4.0	0.0	1.0	25
South Coast Hwy	H009	447.6	472.6	25	90.0		40	1	15	11.4	1.0	4.8	51
South Coast Hwy	H009	472.6	497.6	25	110.0		24	2	8	10.0	2.0	3.4	54
South Western Hwy	H009	29.1	54.1	25	110.0	3902	23	5	6	7.1	2.0	2.0	56
South Western Hwy	H009	54.1	79.1	25	110.0	5528	54	5	11	19.7	4.5	7.0	58
South Western Hwy	H009	79.1	104.1	25	110.0	3643	39	6	10	8.4	2.0	3.2	62

Road Name	Road #	Start True	End True	Seg Length	Speed	2018 AADT	Total Crashes	Total Head On	Total off path	KSI metric	KSI metric Head On	KSI metric offpath	KSI metric % (off path + head on)/total
South Western Hwy	H009	104.1	129.1	25	110.0	3653	32	0	11	9.7	0.0	7.2	74
South Western Hwy	H009	129.1	154.1	25	80.0	4134	33	3	8	10.0	1.8	2.8	46
South Western Hwy	H009	154.1	179.1	25	110.0	7988	40	3	6	11.7	2.8	2.2	42
South Western Hwy	H009	179.1	204.1	25	100.0	4260	49	4	16	11.3	0.8	5.8	58
South Western Hwy	H009	204.1	229.1	25	100.0	3028	24	1	13	7.3	1.0	5.4	88
South Western Hwy	H009	229.1	254.1	25	110.0	2618	24	0	8	8.1	0.0	3.2	39
South Western Hwy	H009	304.1	329.1	25	90.0	375	12	0	10	5.3	0.0	4.8	91
Sues Rd	M081	0.0	25.0	25	110.0	987	11	0	6	4.7	0.0	3.8	81
Toodyay Rd	M026	13.2	38.2	25	90.0	1776	29	2	13	8.7	0.0	7.2	83
Vasse Hwy	M008	0.0	25.0	25	110.0	1394	14	2	5	5.6	0.0	3.0	54
Vasse Hwy	M008	125.0	150.0	25	95.0	1370	14	0	6	6.1	0.0	3.6	59
Williams Kondinin Rd	H053	4.6	29.1	24		1049	10	1	6	3.7	0.8	2.6	90

3.2 Crash profile and traffic volume

Figure 3-2A shows the KSI metric density for all crashes, run-off road and head-on crashes by traffic volume (AADT) for all non-divided road sections included in this study. Figure 3-2B has the same information for the KSI metric rate. This indicates that it is when the traffic volume approaches 6000 AADT that head on crashes begin to be more likely than run-off road crashes. Table 3-3 indicates road sections where the traffic volume will reach or exceed 6000 AADT by 2028. The particular road sections that should be considered include:

- Albany Highway (53.1 – 78.1) South of Jarrahdale
- Brand Highway (11.4 – 36.4) South of Gingin
- Bussell Highway (52.6 – 77.6, 77.6 – 102.6) North to South of Cowaramup
- Great Eastern Highway (57.5 – 82.5, 82.5-107.5, 107.5-132.5) from west of Bakers Hill, Northam and then Meckering. (The Meckering section beginning at 107.5 was not identified as a high risk road section).
- Indian Ocean Drive (6.5 – 31.5) North of Two Rocks
- Pinjarra Williams Road (0.0 – 25.0) North of Dwellingup
- South Western Highway (29.1-54.1, 54.1-79.1, 129.1-134.1) north of North Dandalup, south of Pinjarra, south of Wokalup

Head-on and run-off road crashes that may become head-on crashes already make up a 70% or more of the KSI metric crashes on the identified sections of Albany Highway, Brand Highway, Indian Ocean Drive and the two sections of South Western highway closer to the metropolitan area. For the other road sections listed, these type of crashes contribute 45-55% of KSI metric crashes. The projected increase in KSI metric crashes on these road sections for the 2024-2028 period ranges from 0-3 other than for Pinjarra Williams Road (Table 3-3). Pinjarra-Williams Road is projected to have a large increase in traffic volume with KSI metric crashes rising from 6.7 to 13.4.

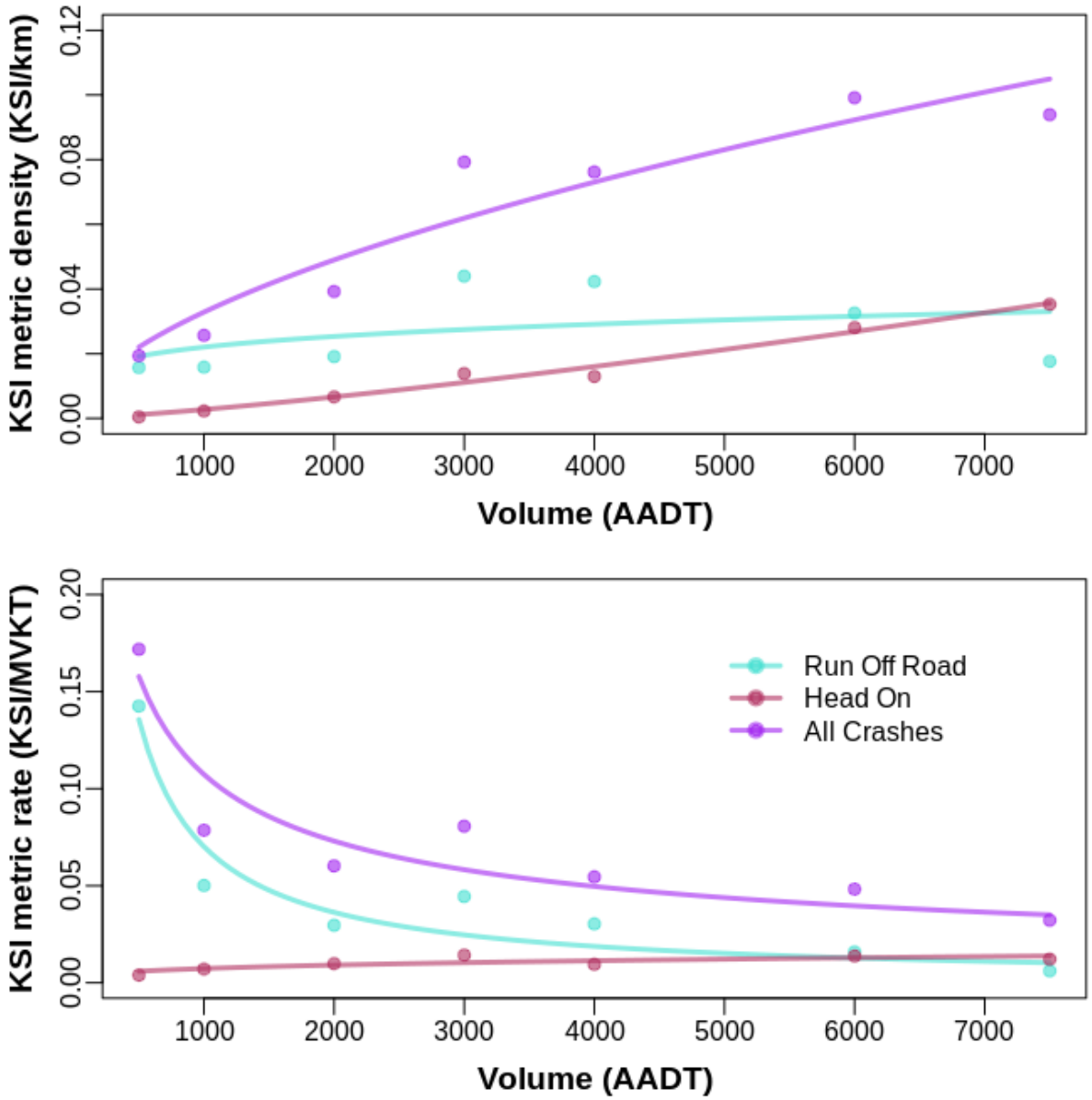


Figure 3-2 KSI metric density and rate vs volume as a function of crash type for roads included in the study (run off road, head on, or all crashes). Note the cross over from run off road crashes to head-on crashes occurs around an AADT of 6000.

3.3 The effect of speed management strategies on KSI crashes

Tables 3-4 and 3-5 show the projected increases in traffic volume on the high risk road sections together with the projected increase in KSI metric crashes. The predicted effect on KSI metric crashes of lowering average speed by either 3, 5 or 10 km/h is also shown. In most cases, a reduction of 10 km/h will counteract the effect of increases in the KSI metric based on traffic volume increases. Exceptions include Brand Highway SLK 11.4-36.4, sections of Forrest Highway, particularly SLK 75.0-100 and Pinjarra Williams Road SLK 0.0-25.0. In the case of a 5

km/h decrease, there are 17 sections of road where there would still be a net increase in the number of KSI metric crashes.

Reduction of average speed by 10 km/h on the combined top 50 high risk road sections across KSI metric density, rate, and combined density and rate ranking has the potential to reduce the KSI metric by 139 crashes during 2024-2028. This is likely to require a reduction in the posted speed limit of around 20-30 kmh. An average speed decrease of 5 km/h would prevent around 70 KSI metric crashes and a 3 km/h decrease would prevent around 42 crashes. These may be achievable with a decrease of 10 km/h in the posted speed limit. However, there is a projected increase of 63 KSI metric crashes as a result of increasing traffic volume. (This is based on 72 out of 79 sections of road with available AADT data).

Table 3-4: Projections to 2028 for KSI metric and estimated effects on crash metrics following 3, 5, and 10 km/h speed reductions.

Road segments with no volume data have been removed

Road Name	Start True	2018 AADT	2028 AADT	2014-2018 KSI metric	Projected KSI metric in 2028	KSI metric increase in 2024-2028		Estimated reduction in projected KSI metric crashes during 2024-2028 with average speed reduction of :					
								3 km/h		5 km/h		10 km/h	
						N	±95% CI	N	±95% CI	N	±95% CI	N	±95% CI
Albany Hwy	53.1	4507	5974	14.7	17.4	2.7	1.6, 4.0	1.7	-1.2, 3.6	2.4	-1.4, 5.0	4.3	-2.2, 8.0
Albany Hwy	78.1	3949	4830	8.9	10.0	1.1	0.7, 1.6	0.6	-0.8, 1.6	0.9	-1.0, 2.4	1.9	-1.8, 3.9
Albany Hwy	103.1	3005	3457	8.6	9.3	0.8	0.4, 1.1	0.7	-0.6, 1.9	1.2	-0.9, 2.6	2.3	-2.1, 4.5
Albany Hwy	128.1	2758	3030	12.6	13.3	0.7	0.4, 1.0	0.7	-0.6, 1.9	1.3	-0.9, 3.0	2.5	-1.6, 5.0
Albany Hwy	153.1	3618	3968	9.3	9.8	0.5	0.3, 0.8	0.7	-0.5, 1.7	1.0	-0.8, 2.4	2.0	-1.7, 4.2
Albany Hwy	278.1	1717	2006	9.3	10.2	0.9	0.5, 1.3	0.6	-0.8, 1.7	1.0	-1.2, 2.6	1.9	-2.5, 4.4
Albany Hwy	303.1	1762	1762	6.6	6.6	0.0	0.0, 0.0	0.4	-0.5, 1.3	0.7	-0.8, 1.9	1.4	-1.8, 3.3
Bindoon Moora Rd	0.0	650	728	5.1	5.5	0.4	0.2, 0.5	0.4	-0.2, 0.9	0.7	-0.2, 1.4	1.4	-0.3, 2.4
Bindoon Moora Rd	25.0	650	728	4.0	4.3	0.3	0.2, 0.4	0.4	-0.1, 0.9	0.8	-0.1, 1.3	1.3	-0.2, 2.2
Bindoon Moora Rd	50.0	650	728	5.6	6.0	0.4	0.2, 0.6	0.4	-0.2, 1.0	0.7	-0.3, 1.6	1.5	-0.6, 2.7
Boyanup Picton Rd	1.0	2320	2686	7.7	8.4	0.7	0.4, 1.0	0.6	-0.4, 1.4	0.9	-0.5, 2.2	2.0	-1.0, 3.6
Brand Hwy	11.4	3657	5535	7.9	10.1	2.2	1.3, 3.3	0.3	-1.4, 1.6	0.8	-1.7, 2.2	1.7	-2.4, 3.7
Brand Hwy	86.4	1738	2532	7.1	9.0	1.8	1.0, 2.7	0.7	-0.9, 1.8	1.1	-1.2, 2.5	2.0	-2.1, 3.9
Bridgetown Boyup Brook Rd	1.6	564	587	3.6	3.7	0.1	0.1, 0.1	0.3	-0.3, 0.7	0.4	-0.5, 1.1	0.8	-1.0, 1.9
Brockman Hwy	50.0	664	743	5.7	6.1	0.4	0.2, 0.6	0.5	-0.4, 1.0	0.6	-0.5, 1.6	1.3	-0.9, 2.6
Brookton Hwy	37.8	1520	1686	6.1	6.5	0.4	0.2, 0.6	0.5	-0.3, 1.1	0.7	-0.5, 1.7	1.4	-1.1, 2.9
Brookton Hwy	62.8	1145	1297	4.1	4.5	0.3	0.2, 0.5	0.2	-0.3, 0.8	0.5	-0.3, 1.0	0.9	-0.6, 1.8
Brookton Hwy	87.8	1046	1072	5.6	5.7	0.1	0.0, 0.1	0.5	-0.1, 0.9	0.7	-0.2, 1.4	1.3	-0.5, 2.6
Bussell Hwy	2.6	16151	20806	22.6	26.3	3.7	2.1, 5.4	1.2	-2.3, 3.8	2.2	-2.8, 5.7	4.7	-4.0, 9.6
Bussell Hwy	27.6	14093	17423	19.5	22.1	2.7	1.5, 3.8	1.0	-1.7, 3.1	1.9	-2.1, 4.9	3.9	-3.5, 8.1
Bussell Hwy	52.6	5610	6978	11.7	13.4	1.6	1.0, 2.4	0.4	-1.1, 1.7	0.9	-1.4, 2.6	2.0	-2.2, 4.5
Bussell Hwy	77.6	6006	7415	19.2	21.8	2.6	1.5, 3.7	0.7	-1.9, 2.7	1.5	-2.3, 4.2	3.3	-3.5, 7.3
Bussell Hwy	127.6	1835	2139	3.7	4.1	0.4	0.2, 0.5	0.2	-0.3, 0.6	0.3	-0.5, 0.9	0.6	-0.8, 1.4
Caves Rd	1.6	9984	11686	11.7	12.9	1.2	0.7, 1.7	0.6	-1.1, 1.9	1.1	-1.6, 3.0	2.3	-3.0, 5.2
Caves Rd	26.6	1357	1357	9.2	9.2	0.0	0.0, 0.0	0.6	-0.2, 1.2	0.9	-0.3, 2.0	1.8	-0.8, 3.5
Caves Rd	51.6	1900	1900	8.9	8.9	0.0	0.0, 0.0	0.6	-0.6, 1.7	1.1	-1.1, 2.6	2.0	-2.4, 4.5
Collie Williams Rd	26.5	361	474	3.6	4.2	0.6	0.4, 0.9	0.4	-0.3, 0.8	0.6	-0.3, 1.3	0.9	-0.6, 1.8

Road Name	Start True	2018 AADT	2028 AADT	2014-2018 KSI metric	Projected KSI metric in 2028	KSI metric increase in 2024-2028		Estimated reduction in projected KSI metric crashes during 2024-2028 with average speed reduction of : 3 km/h		5 km/h		10 km/h	
						N	±95% CI	N	±95% CI	N	±95% CI	N	±95% CI
Corrigin Kondinin Rd	226.9	326	332	3.0	3.0	0.0	0.0, 0.0	0.3	0.0, 0.5	0.4	0.0, 0.7	0.8	0.1, 1.3
Dumbleyung Lake Grace Rd	187.9	390	390	4.0	4.0	0.0	0.0, 0.0	0.3	-0.3, 0.8	0.5	-0.5, 1.2	0.9	-1.2, 2.1
Forrest Hwy	0.0	12305	17171	7.3	8.9	1.6	0.9, 2.4	0.4	-1.0, 1.4	0.7	-1.4, 2.2	1.5	-2.4, 3.5
Forrest Hwy	25.0	14512	19852	13.2	15.9	2.7	1.6, 4.0	0.6	-1.8, 2.3	1.2	-2.2, 3.4	2.5	-3.4, 5.7
Forrest Hwy	50.0	15406	20856	30.6	36.8	6.1	3.5, 9.0	1.3	-4.0, 5.2	2.6	-4.7, 7.7	5.9	-6.8, 12.9
Forrest Hwy	75.0	16361	23092	10.3	12.7	2.4	1.4, 3.5	0.0	-1.8, 1.2	0.4	-1.8, 1.8	1.5	-1.8, 3.4
Great Eastern Hwy	57.5	6147	6147	22.7	22.7	0.0	0.0, 0.0	1.5	-0.7, 3.4	2.5	-1.2, 5.5	4.8	-2.8, 9.6
Great Eastern Hwy	82.5	5757	6797	14.3	15.8	1.5	0.9, 2.2	1.2	-0.7, 2.8	2.1	-0.9, 4.1	3.8	-1.4, 6.9
Great Eastern Hwy	282.5	1552	1641	5.6	5.8	0.2	0.1, 0.3	0.5	-0.1, 0.9	0.8	0.0, 1.5	1.5	0.1, 2.5
Great Northern Hwy	41.5	3203	4029	14.6	16.8	2.2	1.2, 3.1	1.1	-1.7, 3.1	1.8	-2.6, 4.6	3.6	-5.1, 7.7
Great Northern Hwy	91.5	1542	1832	7.0	7.8	0.8	0.4, 1.1	0.8	-0.4, 1.6	1.2	-0.6, 2.3	2.1	-1.3, 3.8
Great Southern Hwy	7.1	1891	1972	13.9	14.2	0.4	0.2, 0.5	1.1	-0.6, 2.3	1.6	-1.1, 3.6	2.9	-2.3, 6.2
Great Southern Hwy	32.1	1342	1342	6.2	6.2	0.0	0.0, 0.0	0.3	-0.1, 0.5	0.4	-0.1, 0.9	0.8	-0.3, 1.7
Great Southern Hwy	111.0	950	950	3.6	3.6	0.0	0.0, 0.0	0.2	-0.1, 0.6	0.4	-0.2, 0.9	0.8	-0.4, 1.6
Great Southern Hwy	211.0	991	991	4.7	4.7	0.0	0.0, 0.0	0.3	-0.1, 0.6	0.5	-0.2, 1.0	0.9	-0.4, 1.8
Great Southern Hwy	236.0	897	993	4.7	5.0	0.3	0.2, 0.4	0.3	-0.3, 0.8	0.4	-0.5, 1.1	0.8	-1.0, 2.0
Great Southern Hwy	261.0	1248	1257	5.7	5.7	0.0	0.0, 0.0	0.4	-0.2, 0.8	0.6	-0.3, 1.3	1.2	-0.7, 2.4
Great Southern Hwy	286.0	538	538	4.1	4.1	0.0	0.0, 0.0	0.4	0.1, 0.6	0.5	0.2, 0.8	0.9	0.2, 1.5
Indian Ocean Dr	6.5	5359	5673	17.6	18.2	0.6	0.4, 0.9	1.2	-0.9, 2.9	1.9	-1.5, 4.5	3.6	-3.0, 7.7
Indian Ocean Dr	31.5	2501	2501	15.0	15.0	0.0	0.0, 0.0	0.9	-0.5, 2.3	1.5	-0.9, 3.6	3.0	-2.1, 6.3
Indian Ocean Dr	56.5	2612	2612	13.6	13.6	0.0	0.0, 0.0	0.8	-0.5, 2.0	1.3	-1.0, 3.2	2.6	-2.1, 5.5
Indian Ocean Dr	206.5	1069	1069	4.1	4.1	0.0	0.0, 0.0	0.3	-0.1, 0.6	0.5	-0.2, 0.9	0.8	-0.4, 1.7
Indian Ocean Dr	231.5	917	917	3.6	3.6	0.0	0.0, 0.0	0.2	-0.2, 0.7	0.3	-0.4, 1.0	0.8	-0.9, 1.7
Midlands Rd	100.0	321	343	3.6	3.7	0.1	0.1, 0.2	0.2	-0.3, 0.7	0.4	-0.5, 1.0	0.7	-1.0, 1.8
Muir Hwy	25.8	365	389	6.7	7.0	0.3	0.2, 0.4	0.4	-0.5, 1.2	0.8	-0.9, 1.9	1.5	-1.8, 3.2
Northam Pithara Rd	78.4	328	341	3.6	3.7	0.1	0.1, 0.1	0.4	0.1, 0.6	0.5	0.1, 0.8	0.9	0.2, 1.5
Northam York Rd	2.6	1284	1454	8.9	9.6	0.7	0.4, 1.0	0.6	-0.4, 1.4	0.9	-0.5, 2.2	2.0	-1.0, 3.7
Nungarin Wyalkatchem Rd	56.6	234	249	4.0	4.2	0.2	0.1, 0.2	0.4	-0.3, 0.9	0.5	-0.6, 1.3	1.0	-1.2, 2.2
Pinjarra Williams Rd	0.0	2021	6323	6.7	13.4	6.6	3.4, 10.9	0.9	-4.9, 3.1	1.5	-5.6, 3.9	3.2	-7.4, 5.7
Pinjarra Williams Rd	25.0	955	1101	6.7	7.3	0.6	0.4, 0.9	0.4	-0.4, 1.3	0.8	-0.6, 1.8	1.5	-1.2, 3.1

Road Name	Start True	2018 AADT	2028 AADT	2014-2018 KSI metric	Projected KSI metric in 2028	KSI metric increase in 2024-2028		Estimated reduction in projected KSI metric crashes during 2024-2028 with average speed reduction of : 3 km/h		5 km/h		10 km/h	
						N	±95% CI	N	±95% CI	N	±95% CI	N	±95% CI
South Western Hwy	29.1	3902	5214	7.1	8.5	1.4	0.8, 2.0	0.7	-0.7, 1.7	1.0	-1.1, 2.4	1.8	-2.4, 3.8
South Western Hwy	54.1	5528	5921	19.7	20.6	0.8	0.5, 1.2	1.4	-0.7, 3.1	2.2	-1.1, 4.7	4.2	-2.3, 8.2
South Western Hwy	79.1	3643	3959	8.4	8.9	0.4	0.3, 0.6	0.5	-0.6, 1.2	0.7	-0.9, 1.9	1.4	-1.7, 3.4
South Western Hwy	104.1	3653	4078	9.7	10.4	0.7	0.4, 1.0	0.9	-0.4, 1.8	1.3	-0.5, 2.6	2.5	-1.0, 4.4
South Western Hwy	129.1	4134	5125	10.0	11.4	1.4	0.8, 2.0	0.8	-0.9, 2.0	1.4	-1.2, 3.0	2.8	-1.9, 5.2
South Western Hwy	154.1	7988	8933	11.7	12.6	0.8	0.5, 1.2	0.6	-0.8, 1.6	0.9	-1.0, 2.4	2.0	-1.8, 4.3
South Western Hwy	179.1	4260	4749	11.3	12.1	0.8	0.4, 1.1	0.5	-0.8, 1.5	0.9	-1.2, 2.4	1.9	-2.2, 4.3
South Western Hwy	204.1	3028	3366	7.3	7.8	0.5	0.3, 0.7	0.6	-0.2, 1.2	1.0	-0.1, 1.8	1.8	-0.1, 3.0
South Western Hwy	229.1	2618	2618	8.1	8.1	0.0	0.0, 0.0	0.6	-0.4, 1.4	1.0	-0.7, 2.1	1.7	-1.6, 3.8
South Western Hwy	304.1	375	375	5.3	5.3	0.0	0.0, 0.0	0.4	-0.3, 0.9	0.5	-0.5, 1.4	1.1	-1.1, 2.3
Sues Rd	0.0	987	1393	4.7	5.8	1.1	0.6, 1.6	0.2	-0.7, 0.9	0.5	-0.7, 1.3	1.1	-1.0, 2.1
Toodyay Rd	13.2	1776	1776	8.7	8.7	0.0	0.0, 0.0	0.7	-0.7, 1.7	1.1	-1.2, 2.7	2.0	-2.6, 4.6
Vasse Hwy	0.0	1394	1560	5.6	6.0	0.4	0.2, 0.6	0.4	-0.5, 1.1	0.6	-0.8, 1.7	1.3	-1.7, 2.9
Vasse Hwy	125.0	1370	1370	6.1	6.1	0.0	0.0, 0.0	0.5	-0.5, 1.2	0.8	-0.8, 1.8	1.4	-1.8, 3.1
Sum				**636.2**	**698.5**	**62.3**	35.5, 91.6	**42.1**	-49.7, 111.8	70.1	-67.6, 168.2	139.2	-120.9, 285.7

Table 3-5: Net changes to KSI metric in 2024-2028 following 3, 5, and 10 km/h speed reductions.

Road segments with no volume data have been removed

Road Name	Start True	2018 AADT	2028 AADT	2014-2018 KSI metric	Projected KSI metric in 2028	Net change in projected KSI for 2024-2028 with average speed reduction of:					
						3 km/h		5 km/h		10 km/h	
						N	±95% CI	N	±95% CI	N	±95% CI
Albany Hwy	53.1	4507	5974	14.7	17.4	-1.1	-2.7, -0.4	-0.3	-2.9, 1.0	1.6	-3.7, 4.0
Albany Hwy	78.1	3949	4830	8.9	10.0	-0.6	-1.5, 0.0	-0.2	-1.7, 0.7	0.8	-2.5, 2.3
Albany Hwy	103.1	3005	3457	8.6	9.3	-0.1	-1.1, 0.9	0.4	-1.4, 1.6	1.5	-2.6, 3.4
Albany Hwy	128.1	2758	3030	12.6	13.3	0.0	-1.1, 0.8	0.5	-1.4, 1.9	1.8	-2.1, 4.0
Albany Hwy	153.1	3618	3968	9.3	9.8	0.2	-0.8, 0.9	0.4	-1.1, 1.7	1.5	-2.0, 3.4
Albany Hwy	278.1	1717	2006	9.3	10.2	-0.3	-1.3, 0.4	0.1	-1.7, 1.3	1.0	-3.0, 3.1
Albany Hwy	303.1	1762	1762	6.6	6.6	0.4	-0.5, 1.3	0.7	-0.8, 1.9	1.4	-1.8, 3.3
Bindoon Moora Rd	0.0	650	728	5.1	5.5	0.0	-0.4, 0.4	0.3	-0.4, 0.9	1.0	-0.5, 1.9
Bindoon Moora Rd	25.0	650	728	4.0	4.3	0.1	-0.3, 0.5	0.5	-0.3, 0.9	1.0	-0.4, 1.8
Bindoon Moora Rd	50.0	650	728	5.6	6.0	0.0	-0.4, 0.5	0.3	-0.5, 1.1	1.1	-0.8, 2.1
Boyanup Picton Rd	1.0	2320	2686	7.7	8.4	-0.1	-0.8, 0.4	0.2	-0.9, 1.2	1.2	-1.4, 2.6
Brand Hwy	11.4	3657	5535	7.9	10.1	-1.9	-2.6, -1.7	-1.4	-2.9, -1.1	-0.5	-3.6, 0.3
Brand Hwy	86.4	1738	2532	7.1	9.0	-1.1	-1.9, -0.9	-0.7	-2.2, -0.2	0.2	-3.1, 1.2
Bridgetown Boyup Brook Rd	1.6	564	587	3.6	3.7	0.2	-0.4, 0.5	0.3	-0.6, 1.0	0.8	-1.1, 1.7
Brockman Hwy	50.0	664	743	5.7	6.1	0.1	-0.6, 0.5	0.2	-0.7, 1.1	0.9	-1.1, 2.0
Brookton Hwy	37.8	1520	1686	6.1	6.5	0.1	-0.5, 0.6	0.3	-0.7, 1.1	1.0	-1.3, 2.3
Brookton Hwy	62.8	1145	1297	4.1	4.5	-0.1	-0.5, 0.3	0.1	-0.5, 0.6	0.6	-0.8, 1.3
Brookton Hwy	87.8	1046	1072	5.6	5.7	0.4	-0.1, 0.8	0.6	-0.2, 1.3	1.3	-0.5, 2.4
Bussell Hwy	2.6	16151	20806	22.6	26.3	-2.5	-4.4, -1.6	-1.5	-4.9, 0.2	1.0	-6.1, 4.2
Bussell Hwy	27.6	14093	17423	19.5	22.1	-1.6	-3.2, -0.7	-0.7	-3.6, 1.0	1.2	-5.0, 4.3
Bussell Hwy	52.6	5610	6978	11.7	13.4	-1.2	-2.1, -0.7	-0.7	-2.4, 0.2	0.3	-3.2, 2.1
Bussell Hwy	77.6	6006	7415	19.2	21.8	-1.9	-3.4, -1.0	-1.1	-3.8, 0.5	0.7	-5.0, 3.5
Bussell Hwy	127.6	1835	2139	3.7	4.1	-0.2	-0.5, 0.0	-0.1	-0.7, 0.4	0.2	-1.0, 0.9
Caves Rd	1.6	9984	11686	11.7	12.9	-0.5	-1.8, 0.2	-0.1	-2.3, 1.3	1.1	-3.7, 3.5
Caves Rd	26.6	1357	1357	9.2	9.2	0.6	-0.2, 1.2	0.9	-0.3, 2.0	1.8	-0.8, 3.5
Caves Rd	51.6	1900	1900	8.9	8.9	0.6	-0.6, 1.7	1.1	-1.1, 2.6	2.0	-2.4, 4.5

Road Name	Start True	2018 AADT	2028 AADT	2014-2018 KSI metric	Projected KSI metric in 2028	Net change in projected KSI for 2024-2028 with average speed reduction of:					
						3 km/h		5 km/h		10 km/h	
						N	±95% CI	N	±95% CI	N	±95% CI
Collie Williams Rd	26.5	361	474	3.6	4.2	-0.2	-0.7, -0.1	0.0	-0.7, 0.3	0.3	-1.0, 0.9
Corrigin Kondinin Rd	226.9	326	332	3.0	3.0	0.3	0.0, 0.5	0.4	0.0, 0.7	0.8	0.1, 1.3
Dumbleyung Lake Grace Rd	187.9	390	390	4.0	4.0	0.3	-0.3, 0.8	0.5	-0.5, 1.2	0.9	-1.2, 2.1
Forrest Hwy	0.0	12305	17171	7.3	8.9	-1.2	-1.9, -0.9	-0.9	-2.3, -0.2	-0.1	-3.3, 1.1
Forrest Hwy	25.0	14512	19852	13.2	15.9	-2.1	-3.4, -1.7	-1.6	-3.8, -0.6	-0.2	-5.0, 1.7
Forrest Hwy	50.0	15406	20856	30.6	36.8	-4.9	-7.5, -3.7	-3.5	-8.2, -1.3	-0.3	-10.3, 4.0
Forrest Hwy	75.0	16361	23092	10.3	12.7	-2.4	-3.2, -2.2	-2.0	-3.2, -1.7	-0.9	-3.2, -0.1
Great Eastern Hwy	57.5	6147	6147	22.7	22.7	1.5	-0.7, 3.4	2.5	-1.2, 5.5	4.8	-2.8, 9.6
Great Eastern Hwy	82.5	5757	6797	14.3	15.8	-0.3	-1.6, 0.7	0.6	-1.8, 2.0	2.3	-2.3, 4.7
Great Eastern Hwy	282.5	1552	1641	5.6	5.8	0.3	-0.2, 0.6	0.6	-0.1, 1.2	1.4	0.0, 2.3
Great Northern Hwy	41.5	3203	4029	14.6	16.8	-1.1	-2.9, 0.0	-0.3	-3.8, 1.5	1.4	-6.3, 4.6
Great Northern Hwy	91.5	1542	1832	7.0	7.8	0.0	-0.8, 0.5	0.4	-1.0, 1.2	1.3	-1.7, 2.7
Great Southern Hwy	7.1	1891	1972	13.9	14.2	0.7	-0.8, 1.8	1.3	-1.3, 3.1	2.6	-2.5, 5.7
Great Southern Hwy	32.1	1342	1342	6.2	6.2	0.3	-0.1, 0.5	0.4	-0.1, 0.9	0.8	-0.3, 1.7
Great Southern Hwy	111.0	950	950	3.6	3.6	0.2	-0.1, 0.6	0.4	-0.2, 0.9	0.8	-0.4, 1.6
Great Southern Hwy	211.0	991	991	4.7	4.7	0.3	-0.1, 0.6	0.5	-0.2, 1.0	0.9	-0.4, 1.8
Great Southern Hwy	236.0	897	993	4.7	5.0	0.0	-0.5, 0.4	0.1	-0.7, 0.7	0.5	-1.2, 1.6
Great Southern Hwy	261.0	1248	1257	5.7	5.7	0.4	-0.2, 0.8	0.6	-0.3, 1.3	1.2	-0.7, 2.3
Great Southern Hwy	286.0	538	538	4.1	4.1	0.4	0.1, 0.6	0.5	0.2, 0.8	0.9	0.2, 1.5
Indian Ocean Dr	6.5	5359	5673	17.6	18.2	0.6	-1.2, 2.0	1.3	-1.8, 3.6	3.0	-3.3, 6.8
Indian Ocean Dr	31.5	2501	2501	15.0	15.0	0.9	-0.5, 2.3	1.5	-0.9, 3.6	3.0	-2.1, 6.3
Indian Ocean Dr	56.5	2612	2612	13.6	13.6	0.8	-0.5, 2.0	1.3	-1.0, 3.2	2.6	-2.1, 5.5
Indian Ocean Dr	206.5	1069	1069	4.1	4.1	0.3	-0.1, 0.6	0.5	-0.2, 0.9	0.8	-0.4, 1.7
Indian Ocean Dr	231.5	917	917	3.6	3.6	0.2	-0.2, 0.7	0.3	-0.4, 1.0	0.8	-0.9, 1.7
Midlands Rd	100.0	321	343	3.6	3.7	0.1	-0.3, 0.5	0.3	-0.5, 0.8	0.6	-1.0, 1.6
Muir Hwy	25.8	365	389	6.7	7.0	0.1	-0.7, 0.8	0.5	-1.1, 1.5	1.2	-2.0, 2.9
Northam Pithara Rd	78.4	328	341	3.6	3.7	0.3	0.0, 0.4	0.4	0.0, 0.7	0.9	0.1, 1.3
Northam York Rd	2.6	1284	1454	8.9	9.6	-0.1	-0.8, 0.4	0.2	-0.9, 1.2	1.3	-1.4, 2.7
Nungarin Wyalkatchem Rd	56.6	234	249	4.0	4.2	0.2	-0.4, 0.7	0.3	-0.7, 1.1	0.8	-1.3, 2.0
Pinjarra Williams Rd	0.0	2021	6323	6.7	13.4	-5.8	-8.2, -7.8	-5.1	-8.9, -7.0	-3.4	-10.7, -5.3

Road Name	Start True	2018 AADT	2028 AADT	2014-2018 KSI metric	Projected KSI metric in 2028	Net change in projected KSI for 2024-2028 with average speed reduction of:					
						3 km/h		5 km/h		10 km/h	
						N	±95% CI	N	±95% CI	N	±95% CI
Pinjarra Williams Rd	25.0	955	1101	6.7	7.3	-0.2	-0.7, 0.4	0.2	-0.9, 0.9	0.9	-1.5, 2.2
South Western Hwy	29.1	3902	5214	7.1	8.5	-0.7	-1.5, -0.3	-0.4	-1.9, 0.4	0.4	-3.2, 1.8
South Western Hwy	54.1	5528	5921	19.7	20.6	0.5	-1.2, 1.9	1.3	-1.6, 3.6	3.3	-2.8, 7.0
South Western Hwy	79.1	3643	3959	8.4	8.9	0.0	-0.8, 0.6	0.3	-1.1, 1.3	1.0	-1.9, 2.8
South Western Hwy	104.1	3653	4078	9.7	10.4	0.2	-0.8, 0.8	0.6	-0.9, 1.7	1.8	-1.4, 3.5
South Western Hwy	129.1	4134	5125	10.0	11.4	-0.6	-1.7, 0.0	0.0	-2.0, 1.0	1.4	-2.7, 3.2
South Western Hwy	154.1	7988	8933	11.7	12.6	-0.2	-1.2, 0.4	0.1	-1.4, 1.2	1.2	-2.2, 3.1
South Western Hwy	179.1	4260	4749	11.3	12.1	-0.3	-1.2, 0.4	0.1	-1.6, 1.3	1.1	-2.6, 3.2
South Western Hwy	204.1	3028	3366	7.3	7.8	0.1	-0.4, 0.5	0.5	-0.3, 1.1	1.4	-0.3, 2.3
South Western Hwy	229.1	2618	2618	8.1	8.1	0.6	-0.4, 1.4	1.0	-0.7, 2.1	1.7	-1.6, 3.8
South Western Hwy	304.1	375	375	5.3	5.3	0.4	-0.3, 0.9	0.5	-0.5, 1.4	1.1	-1.1, 2.3
Sues Rd	0.0	987	1393	4.7	5.8	-0.9	-1.3, -0.7	-0.6	-1.3, -0.3	0.0	-1.6, 0.5
Toodyay Rd	13.2	1776	1776	8.7	8.7	0.7	-0.7, 1.7	1.1	-1.2, 2.7	2.0	-2.6, 4.6
Vasse Hwy	0.0	1394	1560	5.6	6.0	0.0	-0.7, 0.6	0.2	-1.0, 1.2	0.9	-1.9, 2.3
Vasse Hwy	125.0	1370	1370	6.1	6.1	0.5	-0.5, 1.2	0.8	-0.8, 1.8	1.4	-1.8, 3.1
Sum				**636.2**	**698.5**	-20.2	-85.1, 20.2	7.8	-103.0, 76.7	76.9	-156.3, 194.2

4. DISCUSSION

Based on IRIS crash data for 2014-2018, our analysis identified a number of sections of road with a high risk of fatal and serious injury crashes on the major routes leading out of Perth into regional areas. In some cases, the level of risk is similar to that which sparked the recent Safe System review on Indian Ocean Drive. In addition, the study has identified that when the traffic volume on undivided roads in the study area reaches around 6000 AADT there is potential for an increase in serious and fatal crashes as head-on collisions become more prominent than run-off road crashes. Future high risk road sections which were included in the study and may reach this traffic volume within the next 2024-2028 period were identified.

These current and future high risk road sections should be prioritised for infrastructure upgrades and potential speed management. A number of these roads are currently on the Main Roads project list or will be treated under the regional run-off road program. Work that is currently scheduled or planned can be found on the Main Roads website. See https://www.mainroads.wa.gov.au/OurRoads/RoadSafety/Pages/regional-run-off-program.aspx and https://project.mainroads.wa.gov.au/home/current/Pages/default.aspx. Prioritisation of infrastructure upgrades should be based on the potential for crash prevention (Main Roads WA, 2016).

Speed management is also an effective method of preventing crashes. Higher vehicle speeds are associated with an increased crash rates and increased injury severity (Aarts et al., 2009; Nilsson, 2004). A 5% increase in mean speed has been show to lead to around a 10% increase in all injury crashes and a 20% increase in fatal crashes (Nilsson, 2004). In accordance with safe system philosophy that people will make mistakes and the road system needs to protect them from harm when this occurs, aspirational safe speeds have been proposed as 70 km/h where there is a possibility of head on collision and greater than 100 km/h only where side and frontal vehicle impacts are not possible and impacts with vulnerable road users are not possible (Austroads, 2018). Ideally, road features and characteristics should promote speeds which are consistent with the safe speeds on the basis of function and design (Wegman and Aarts, 2006). In places where infrastructure improvements are not currently viable, speed management is an effective means of reducing the risk of serious crashes.

An infrastructure risk rating score (IRR) appropriate for speed limit setting has been developed as part of the New Zealand Speed Management Framework (Durdin et al., 2016; Zia et al., 2016). This can be calculated for the entire road network as it uses data from the Road Assessment and Maintenance Management (RAMM) databases. Trials of the IRR in Western Australia have shown it can accurately predict fatal and serious injuries on rural roads, particularly when speed risk factors are taken into account. Application of this model to high risk roads in Western Australia would help to provide a logical basis for speed limit setting which could be presented and justified to the public.

Nevertheless, enforcement is likely to be required to promote lowering of the speed limit. In regional areas this is likely to include point-to-point speed cameras, mobile speed cameras and fixed speed cameras. Evidence shows that all three methods can be effective (ARRB Group, 2005; De Pauw et al., 2014a; Hoye, 2015; Newstead et al., 2014; Soole et al., 2013).

Successful reduction of posted speed limits and the resulting average speed also depends on community acceptance and compliance as enforcement can only target limited sections of the road network at any one time. Therefore education and publicity campaigns will be required in tandem with enforcement programs. A recent Austroads report provides guidance on engagement for speed management (Austroads, 2019). The following best practice guidelines were presented (page 87):

- "Undertake surveys to understand public attitudes towards speed. This is necessary to ensure messages around speed management are relevant and targeted.
- Engagement and consultation should focus on speed and its close link to road safety outcomes rather than speed limits.
- Engagement should be undertaken throughout the project phase, but especially before the formal consultation process. It is important for road controlling authorities to explain their strategic objectives early to build understanding and support for speed management interventions.
- While state authorities are responsible for setting speed limits, there is scope for a shared role between state and local authorities in community and stakeholder engagement.

High-level strategic direction from the state authority, coupled with the local knowledge of local authorities, is considered good practice.

- State authorities should take responsibility for supporting local authorities in their engagement and consultation practices by providing training, tools and templates, and support for developing and resourcing communication strategies.
- State and local authorities should listen to and consider the views of stakeholders and the public.
- Engagement and consultation should use a range of media to ensure wide coverage.
- Speed management interventions should be planned and implemented at a pace at which stakeholders and the public can accept and support."

In addition to major infrastructure investment and reducing the speed limit, various engineering features are available to help manage speeds (Austroads, 2016). Many of these are focussed on warning motorists of an impending hazard such as a curve, intersection, or roundabout. They can include actual or perceptual lane narrowing, road markings such as transverse lines or converging chevrons, rumble strips and signs. Curve treatments that indicate the severity of the curve can also help to reduce speed. Lane narrowing by means of wide median centreline treatments has potential for reducing speeds on high-speed roads as roadway width has been shown to influence travel speeds (Austroads, 2016).

Availability of Intelligent speed adaptation (ISA) in vehicles is a further strategy to help keep vehicles within the speed limit. ISA warns drivers to keep within the speed limit using visual or audible feedback. It identifies the speed limit using Global Navigation Satellite System technology and onboard maps linked to a speed zone database. Modelling based on a trial of ISA in the UK found that injury crash reduction rates could be reduced by around 10-20% on roads with a 60 mph speed limit (Lai et al., 2012). An ISA trial in New South Wales showed that 89% of drivers reduced their amount of time speeding when the ISA device was fitted and that there was a 32% reduction in speeding (Wall et al., 2016). Extrapolation of data from this trial suggest that ISA has the potential to reduce fatal and serious injury crashes in Australia by 19%. Other technologies that may also assist include safe vehicle technologies such as lane deviation warning, lane keep assist, forward collision warning and driver attention assist (Palamara, 2018).

4.1 Limitations

The crash reduction modelling of speed changes using the power function from Elvik et al. (2009) are not based exclusively on Western Australian roads and infrastructure, nor do they take into account more recent improvements in vehicle safety over time. Therefore, it is unclear whether the modelling considerably over- or under-estimates the safety benefit from a speed reduction. However, Elvik's models are based on a large data base containing estimates of the relationship between speed and crash risk and a comparable breadth of data for estimation of statistically robust Australian specific models is not available.

Traffic volume was based on AADT (Annual Average Daily Traffic). AADT does not account for fluctuations in traffic by time of day or time of year.

Projected volumes are, in a number of instances, projected twice: once from the recording date (which may have been as early as 2012-2013) to 2018, and then projected again from 2018 to 2028. Therefore, in addition to the uncertainty in projecting of traffic volumes ten years into the future, the traffic volume on some road sections have been projected 16 years into the future which increases the level of uncertainty. This likely affects lower volume roads more than higher volume roads, which increases the uncertainty primarily in the estimates of KSI metric rate, with little influence on KSI metric density. Related to this, a number of sites that may be of interest did not have suitable traffic volume data, potentially excluding high-risk road sections from the analysis of KSI metric rate. Again, this would not affect KSI metric density.

We have projected traffic crashes based on historical crash trends and traffic volume data. Ideally crash prediction models would include contributing factors such as driver behaviour, vehicle characteristics, roadway geometry and road-environment conditions (Abdulhafedh, 2017) and should be constructed separately for individual homogenous road sections. The predictive method adopted by the American Association of State Highway and Transportation Officials (AASHTO) in the Highway Safety Manual is based on geometric design for a given time period with specific traffic control features and traffic volumes(American Association of State Highway and Transportation Officials (AASHTO), 2010). Our projections are simplified in that

they are based on all single carriageway roads included in the study. More accurate predictions following the AASHTO or a similar method should be considered in the future.

The relationship between AADT and fatal and serious injuries should ideally also be based on homogenous road sections. Figure 3-2 has averaged this relationship across road sections included in the study and not taken account of geometric factors.

In calculating the likely reduction in KSI crashes associated with a decrease in the posted speed limit we have used the average speed on rural roads with relevant speed limits taken from the 2013 speed survey (Radalj and Sultana, 2014). The standard deviation around the average estimate of 100.2 km/h for 110 km/h roads in rural areas in 2013 was 14.7. There is thus considerable variation in average speeds across the road network by location which we were unable to account for.

Analysis of road segments was done for 25 km road sections and excluded sections less than half of this length (i.e., 12.5 km). This number was chosen because of the focus on high speed regional and remote roads that can sometimes stretch for hundreds of km in the South West of WA. We evaluated different lengths of roads (for example 10 km and 50 km), but did not find substantial changes in the rankings.

4.2 Conclusion

The results of this study suggest that reducing speed limits on high risk road sections in Western Australia could be a successful strategy in reducing current road trauma and addressing the projected increase in road trauma as a result of increasing traffic volumes. Success would be dependent on effective community engagement. A speed reduction strategy needs to sit together with infrastructure improvements specifically aimed at “corridor protection”. A further component of the strategy should be the promotion of safer vehicles.

5. RECOMMENDATIONS

i. All current and future high risk road sections should be considered for infrastructure upgrades where this is not currently scheduled.

ii. Posted speed limits should be set based on the infrastructure risk rating. Where the posted speed limit is higher than that recommended as suitable for the infrastructure, it should be reduced to that which is safe for the level of infrastructure provided. As it is unlikely that large reductions in posted speed limit will be acceptable to the community it is recommended that speed limits are brought down gradually.

iii. Successful reduction of speed limits depends on community acceptance and compliance with this strategy. This will require education and publicity campaigns in tandem with enforcement programs. Community engagement with regards high risk roads should be undertaken throughout the process, as part of infrastructure improvement as well as speed management.

iv. Updating of traffic volume data across the network to a more recent time point would be valuable in improving accuracy estimates.

v. That infrastructure risk rating and crash prediction be undertaken across the West Australian road network at the small area level incorporating updated traffic volume estimates to improve the identification of current and future high risk road sections and to allow improved estimation of the effect of infrastructure improvement and speed management strategies.

vi. Promotion and adoption of vehicles with technologies such as intelligent speed adaptation, lane deviation warning, lane keep assist, forward collision warning and driver attention assist needs to continue as this will contribute to preventing fatal and serious injury crashes.

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7. Appendix - Exclusion zones for regional towns

Exclusion zones for regional towns (metres)

Locality	Exclusion Radius (m)
ALBANY	10247
AUGUSTA	544
AUSTRALIND	2847
BODDINGTON	522
BRIDGETOWN	1062
BUNBURY	12473
BUSSELTON	5321
BYFORD	1051
CAPEL	629
COLLIE	3597
DENMARK	989
DONGARA	937
DONNYBROOK	818
DUNSBOROUGH	577
EAST BULLSBROOK	568
EATON	2035
GELORUP	864
GERALDTON	12622
GOLDEN BAY-SINGLETON	1836
HARVEY	1285
KATANNING	2018
KOJONUP	518
LESCHENAULT	955
MANDURAH	17973
MANJIMUP	2195
MARGARET RIVER	1423
MERREDIN	1456
MOORA	832
MOUNT BARKER	824
MOUNT HELENA	913
MUNDARING	956
NARROGIN	2246
NORTH PINJARRA	506
PARKERVILLE	690
PINJARRA	946
ROCKINGHAM	24959
STONEVILLE	916
WAGIN	669
WAROONA	917
YANCHEP	895

YORK	962
YUNDERUP	876