Motorcycle safety in Western Australia: review of popular routes, crash risk factors and options to improve current state, based on Safe System approach

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Title
Motorcycle safety in Western Australia: review of popular routes, crash risk factors and options to improve current state, based on Safe System approach

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Abstract
This study examined factors affecting risk of motorcycle crashes and identified areas with clusters of motorcycle crashes. Crashes tended to cluster at certain large intersections with nine intersections experiencing eight or more motorcycle crashes between 2013 and 2017, and along sections of Kwinana and Mitchell Freeways, with up to 20 motorcycle crashes per road section in the Perth metropolitan areas. In regional and remote WA, the highest numbers of crashes occurred in and around Bunbury, Geraldton, Albany, Broome and Kalgoorlie. Recommendations are made to reduce risk of motorcycles crashes, with a specific focus on infrastructure changes aimed at creating a more motorcycle friendly road network.

Keywords
Crash, Road Safety, Motorcycle safety, Safe System approach

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EXECUTIVE SUMMARY

Introduction

Motorcyclists are vulnerable road users and are susceptible to injury because they are unprotected by an external protective device. They are less visible to other vehicle drivers and are more sensitive to road infrastructure irregularities.

In 2015, the Motorcycle Safety Review Group (MSRG) was commissioned to address an increase in fatal motorcycle crashes from 27 in 2013 to 44 in Western Australia (WA) in 2014 (Motorcycle Safety Review Group, 2015). Despite representing only 6% of all registered vehicles in WA, 16% (n=26) of all fatalities in WA in 2017 were motorcyclists (Road Safety Commission, 2018).

The MSRG developed a strategic plan to guide improvements in safety for motorcyclists within the Safe System framework. This project aims to address aspects of this strategic plan.
The study will analyse the crash risk profile of WA motorcyclists involved in crashes and identify high-risk routes with clusters of motorcycle crashes.

Objectives

The objectives of this part of the study were as follows:

1. Examine the pattern of motorcyclist crashes in WA between 2013 and 2017 to identify risk factors for these crashes.
2. Identify clusters of motorcycle crashes and high-risk routes on the WA road network. (This addresses Action 34[1] of the Motorcycle Strategic Plan.)
3. Review the literature, with emphasis on Australia and New Zealand, on treatments available to address issues on identified routes.
4. Make recommendations to improve areas where clusters of crashes have been identified.

The study used a longitudinal retrospective population-based study design (2013 to 2017). The study area was the state of Western Australia.

[1] Action 34 - Assess a small number of popular routes using a skilled and experienced rider communicating to a following vehicle, to identify the potential for a mass action treatment of issues.
MOTORCYCLE SAFETY REVIEW GROUP 2015. Western Australian strategy direction for improving the safety of motorcyclists and moped riders. Perth: Road Safety Commission.

Research methods

Review of literature

Multiple sources were used to undertake a review of literature up to early 2019. These included the websites of government agencies, and road safety information organisations. In addition, grey literature (primarily technical reports and conference papers) and published, peer-reviewed journal articles were sourced.

Crash analysis data requirements

Five years of crash data was extracted from the Integrated Road Information System (IRIS), maintained by Main Roads Western Australia. Crash data was requested for the period 1 January 2013 to 31 December 2017 for the whole of WA. Crashes was be flagged as involving motorcyclists (using the 'U-type' variable). All crashes involving motorcyclist reported in the IRIS were included in the study, including fatal, hospitalisation, medical treatment only and property damage only (PDO) crashes.

A map was created using a geographic information system. All crashes involving motorcyclists were plotted on the map and joined to the road network.

Analysis

Crash data was summarised using frequencies of demographic characteristics of motorcyclists, crash type and characteristics, road characteristics and time of day.

High risk routes for motorcycle crashes were identified using four methods:

1) Heat maps indicating crash density;
2) The count of motorcycle crashes per postcode;
3) The count of motorcycle crashes per intersection;
4) The count of motorcycle crashes per road section.

Virtual inspections of high motorcycle crash risk areas

Virtual inspections were undertaken of high-risk areas using the Main Roads Road Information Mapping System, Nearmap and Google Maps. Characteristics of the motorcycle crashes in these high-risk areas were also examined.

Literature Review

Motorcycles have become an increasingly popular form of transport. They have several advantages over cars: they are efficient in congested areas, require less space to park than cars, have lower running costs (fuel and maintenance), and have a lower impact on the environment (EuroRAP, 2008). They provide an alternative to public transport, allowing longer distances to be travelled than walking and cycling (EuroRAP, 2008). However, motorcyclists are considered vulnerable road users. This vulnerability is due to several contributory factors: characteristics of motorcycle, the environment, and behavioural factors.

Factors affecting motorcycle crashes

Demographic factors

Male motorcyclists predominant in motorcycle fatalities in Australia and other countries. In Australia, more fatalities occur among motorcyclists under 40 years of age in urban areas, while fatalities among motorcyclists over 40 years old tend to occur in regional and remote Australia (BITRE, 2017a).

Motorcycle skill- and vehicle-related factors

Risk of crash and serious injury is higher among motorcyclists without a licence (Lin and Kraus, 2009) and those with less experience (Wali et al., 2018). Research found that motorcyclists riding an unfamiliar motorcycle or using a sports motorcycle were more likely to be involved in a crash than other motorcyclists (Brown et al., 2015).

Risk-taking behaviour

A six-year analysis of fatal motorcycle crashes in Australia found that some form of risky riding behaviour was identified as a contributory factor among half (n=663) of fatalities (Bambach et al., 2012). The risky behaviours included excessive speed, alcohol, drugs and disobeying a traffic control law. Fatigue is a further risk for crashes, and can lead to poor attention, slowed reaction times, impaired judgement and risk of falling asleep (Vlahogianni et al., 2012).

Higher riding speed is a common contributory factor to motorcycle crashes and is associated with more serious injuries than lower speeds (Lin and Kraus, 2009).

As in crashes involving only motor vehicles, alcohol has been found to be a major contributor to both non-fatal and fatal motorcycle crashes (Jones et al., 2013). Other drugs, including prescription drugs such as benzodiazepines and illicit drugs such as marijuana and cocaine, have frequently been used, often with alcohol, among motorcyclists involved in motorcycle crashes (Lin and Kraus, 2009).

Time of day, weather and road conditions

National data in Australia shows that motorcycle fatalities peak between 9am and 9pm, with a third of all crashes occurring between 9am on Saturday and 9pm on Sunday (BITRE, 2017b). Two-thirds of 273 known cases of fatal crashes between 2001 and 2006 with weather data occurred in fine, dry conditions on a dry road surface (Bambach et al., 2012).

Crash location and crash type

A study conducted in Western Australia found that more than a third of fatal crashes occurred on regional and remote roads (Palamara et al., 2013). National statistics from 2013 to 2015 demonstrated that less than half of motorcycles crashes involved a single vehicle. Of all single vehicle fatal motor cycles, 65% involved a non-collision on a curve, and 27% involved a non-collision on the straight (BITRE, 2017a).

Research has found that severe and fatal motorcycle crashes are more likely to occur at intersections than at other locations (Vlahogianni et al., 2012), with right-of-way violations representing the most common type of crash.

Conspicuity

Studies have found that poor visibility and darkness are associated with great motorcycle injury severity, both because of the motorcyclists' ability to see and be seen (Vlahogianni et al., 2012). Conspicuity has two aspects: the visibility of the motorcycle itself, and of the rider of the motorcycle. Interventions to improve the conspicuity of the motorcycle include using daytime headlight laws (Davoodi and Hossayni, 2015). Clothing which increases conspicuity can also be used, including reflective vests and other high visibility clothing.

Motorcycle safety features

In recent years, safety features are being developed which can protect the motorcyclist both from a crash and reduce the severity of a crash. These include:

i) Airbags;

ii) Motorcycle Stability Control (MSC);

iii) Linked Braking System (LBS) which can be combined with the Anti-lock Braking System (ABS); and

iv) Electronic Control Unit (ECU) to ensure that traction with the road is maintained (VicRoads, 2015).

An Australian study found that the presence of ABS on a motorcycle was associated with a 33% reduction in all injuries and 39% reduction in severe injuries in crash types where ABS was likely to be beneficial (Fildes et al., 2015).

Use of helmets

A Cochrane review of the use of helmets to prevent injury in motorcycle crashes found that helmets reduce risk of death by 42% and reduced risk of head injury by 69% (Liu et al., 2008).

Use of protective clothing

Protective clothing (footwear, tops and pants, and gloves) can reduce the severity of an injury to a motorcyclist involved in a crash (de Rome et al., 2014).

Road design and infrastructure, including crash barriers

Although road infrastructure should be designed to accommodate every road user (BITRE, 2017a), roads tend to be designed around the needs of motor vehicles, rather than motorcycles and other vulnerable road users. Road features which impact on motorcyclists include slippery road surfaces, manhole covers without skid resistance treatment, intersection design, signage, pole locations and crash barriers (Vlahogianni et al., 2012, BITRE, 2017a). There is concern, particularly from the motorcyclist community, that one type of guard rail, the wire rope barrier, does not protect motorcyclists as effectively as other road users, and may result in more severe injuries (BITRE, 2017a). Milling and colleagues (2016) discuss motorcyclist-friendly crash barriers such as the use of flexible fabric mesh on existing barriers and retrofitting under-run protection to w-beam barriers.

Results

<u>Descriptive statistics</u>

A total of 6,723 crashes involving motorcycles[2] occurred in WA between 2013 and 2017. Of those with age and sex recorded, the highest proportion of motorcyclists and passengers were

[2] The term 'motorcycle' includes motorcycles, mopeds and scooters, unless otherwise specified.

between 16 and 24 years old (n=1,204, 22%). Males made up 87% (n=4,853) of those on motorcycles involved in crashes.

Of those involved in crashes on a motorcycle with a recorded injury (n=3,258, 45% of persons on a motorcycle involved in a crash), 161 (4.9%) were fatally injured. More than half (n=1,735, 53%) required admission to hospital for treatment of their injuries. A relatively higher proportion of fatal crashes occurred in inner and outer regional and remote WA, compared to in the Perth metropolitan area.

Of those involved in motorcycle crashes with licencing data recorded, the highest proportion of unlicenced motorcyclists was in the 25 to 29 year old age-group (n=165, 33%). More than three-quarters of crashes occurred in the daylight hours (n=5,102, 77%). A peak of 702 (11%) crashes occurred between 4pm and 4:59pm.

Most motorcycle crashes in WA between 2013 and 2017 involved multiple vehicles (n=5,039, 75%). Just over half of motorcycle crashes occurred at intersections (n=3,401, 51%). Nearly a quarter of crashes were rear-end crashes (n=1,543, 24%), with 20% of crashes being right-angle crashes (n=1,275) and a further 20% being non-collisions (n=1,291).

High-risk areas for motorcyclists

High-risk metropolitan intersections, high-risk metropolitan road sections and high risk regional and remote areas for motorcyclists were identified using all[3] crashes involving motorcycles, and analysed as follows:

High-risk metropolitan intersections

a) Tonkin Highway and Collier Road, Bayswater (intersection number 4541): a four-way signalised intersection, later converted to an interchange, with 11 motorcycle crashes over the study period;
b) Burns Beach Road and Connolly Drive, Currambine (intersection number 75717): a double-lane roundabout, with 10 motorcycle crashes over the study period; and
c) Thomas Street/Bagot Road and Kings Park Road, West Perth (intersection number 50693): a four-way signalised intersection, with 9 motorcycle crashes over the study period.

[3] All crashes included fatal, hospitalisation, medical treatment only and PDO crashes.

High-risk metropolitan road sections[4]

a) Kwinana Freeway, Success/Atwell: 20 motorcycle crashes per road section over the study period;
b) Kwinana Freeway, South Perth/Como: 16 motorcycle crashes per road section over the study period;
c) Nicholson Road, Canning Vale/Thornlie: 13 motorcycle crashes per road section over the study period;
d) Kwinana Freeway, Cockburn Central/Jandakot: 12 motorcycle crashes per road section over the study period;
e) Collier Road, Bayswater (all occurred at the intersection Tonkin Highway, above): 11 motorcycle crashes per road section over the study period; and
f) Mitchell Freeway, Leederville: 11 motorcycle crashes per road section over the study period.

High-risk regional and remote areas

a) Bunbury (postcode 6230): 115 motorcycle crashes over the study period;
b) Geraldton (postcode 6530): 92 motorcycle crashes over the study period;
c) Albany (postcode 6320): 85 motorcycle crashes over the study period;
d) Kalgoorlie (postcode 6430): 60 motorcycle crashes over the study period; and
e) Broome (postcode 6725): 59 motorcycle crashes over the study period.

Recommendations

Recommendations relating to infrastructure at metropolitan intersections

- Improving sight distance for cars and motorcycles for some intersections so that other road users are more easily able to see motorcyclists and motorcyclists have more time to take evasive action.
- Adapting car and truck sight distance within roundabouts so that motorcyclists are clearly visible but do not travel at too quickly, especially on the approach.
- Improved street lighting could also be used at high-risk intersections to improve visibility of motorcyclists.

[4] Road sections were defined using the network element identifier, the IRIS unique network element identifier variable.

- Warning signage and pavements markings could be used to alert drivers to the intersection ahead and the presence of motorcycles.
- A motorcycle lane could be provided specifically at high-risk intersections, or lanes could be widened to allow motorcycles to filter to the front of the queue. Advance stop lines could be provided, allowing motorcyclists to stop ahead of other road users at the intersections and move off before them when the traffic signal changes.
- Traffic signal phases should be optimised to allow motorcycles to clear intersections. Traffic filter lights may be installed specifically to control right turning vehicles.

Recommendations relating to infrastructure on freeways

- Improved sight lines, especially around curves. This could include removal or moving of poles, vegetation or fixed objects which interfere with the line of sight.
- Road surfaces should be optimised in high-risk, high motorcycle volume sections of freeways. This would include skid resistant pavement markings, correcting road camber and improving drainage.
- The viability and effectiveness of exclusive motorcycle lanes needs further investigation.
- Treatment of guard rails to protect motorcyclists from more severe injuries in the event of a crash along high-risk sections of the freeway.

Recommendations relating to infrastructure on non-freeway metropolitan roads

- Improving the condition of roads to reduce the risk of motorcycles crashes through interventions and timely repairs to damaged surfaces.
- Removal of roadside hazards to improve sight distance.
- Improve street lighting in high-risk areas.

Recommendations relating to infrastructure on regional and remote areas

- Maintenance of these roads should include maintaining skid resistance roads and pavement markings, sweeping, trimming trees, sealing joints, ensuring adequate drainage and street lighting.
- Potholes, ruts and corrugation should be repaired as soon as possible, but warning signs should be used if repairs are delayed.
- The placement of ‘roadside furniture’ should be carefully considered.

- Motorcycle specific signage, raising awareness of dangers of the road to motorcyclists along windy stretches of road.
- The installation of motorcycle friendly guard rails in higher volumes, windy routes, popular with recreational motorcyclists.

1 INTRODUCTION

Motorcyclists are vulnerable road users and are susceptible to crash injury because they are unprotected by an external protective device (such as a motor vehicle body). They are less visible to other vehicle drivers and are more sensitive to road infrastructure irregularities. Previous Australian research has shown that drivers under 25 years and males were over-represented in fatal and hospitalised injury crashes (Palamara et al., 2013). An analysis of West Australian (WA) motorcyclist crash data in 2013 and 2014 showed that alcohol, illicit drugs and speeding were frequently involved in fatal motorcyclist crashes (Motorcycle Safety Review Group, 2015).

In 2015, the Motorcycle Safety Review Group (MSRG) was commissioned by the then Minister for Road Safety, Hon. Liza Harvey MLA, to address a large increase in fatal crashes from 27 in 2013 to 44 in 2014 in WA (Motorcycle Safety Review Group, 2015).

The MSRG was tasked to examine issues and further options that could be pursued to improve motorcycle and moped safety in WA. The MSRG was chaired by the Road Safety Commission (RSC, Office of Road Safety prior to 1 July 2015) and included representatives from the Department of Transport, WA Police, Main Roads WA and Insurance Commission of WA (Motorcycle Safety Review Group, 2015).

The working group produced the *'Western Australian Strategic Direction for Improving the Safety of Motorcyclists and Moped Riders 2016-2020'* which lays out 39 actions to improve motorcycle safety. In summary, these aimed to: encourage motorcyclists to be responsible to their own and others' safety; improve interactions between motorcyclists and other road users; make the road and roadside more *"motorcycle friendly*"; and improve uptake of motorcycles with safety features (Motorcycle Safety Review Group, 2015).

One of these actions, Action 34 *"Assess a small number of popular routes using a skilled and experienced rider communicating to a following vehicle, to identify the potential for a mass action treatment of issues. (Roads and roadsides – more motorcycle friendly transport system)"* - Section 4.4.7 Popular and high risk routes (pp. 41 Motorcycle Safety Review Group, 2015). One such *'existing conditions motorcycle audit'*, commissioned by the RSC and undertaken by Safe Systems Solutions, analysed Toodyay Road (from Midland to Toodyay) (Beer and Wright, 2016). The audit found no high-risk issues for motorcyclists but found several low- and medium-risk issues on the road. These included issues around the following: i) edge drop offs, unsealed bellmouths, side roads and pull-over areas; ii) barrier kerbing near edgelines; iii) signage; iv) guard rails; v) surface and lane width; and vi) culverts without endwalls.

This project, conducted on behalf of the Road Safety Commission, extended this work by identifying high risk routes across the state. Virtual route inspections, rather than a motorcycle rider, were used because for the scope of the project (examining high risk areas throughout WA).

1.1 Aims

The aim of the study was to identify the crash risk profile of WA motorcyclists involved in crashes, and identify high risk routes with clusters of motorcycle crashes.

1.2 Objectives

The objectives of this study were as follows:

1. Examine the pattern of motorcyclist crashes in WA between 2013 and 2017 to identify risk factors for these crashes;
2. Identify clusters of motorcycle crashes and high-risk routes on the WA road network. (This addresses Action 34[5] of the Motorcycle strategic plan.)
3. Review the literature, with emphasis on Australia and New Zealand, on treatments available to address issues on identified routes.
4. Make recommendations to improve areas where clusters of crashes have been identified.

The study used a longitudinal retrospective population-based study design. The study area was the state of Western Australia.

[5] Action 34 - Assess a small number of popular routes using a skilled and experienced rider communicating to a following vehicle, to identify the potential for a mass action treatment of issues MOTORCYCLE SAFETY REVIEW GROUP 2015. Western Australian strategy direction for improving the safety of motorcyclists and moped riders. Perth: Road Safety Commission..

2 METHODS

2.1 Study Design

This study consisted of a literature review followed by a retrospective population-based crash data analysis (including spatial analysis) of the state of WA, and provision of recommendations based on the study findings, the literature and policy in other jurisdictions.

2.2 Review of literature

Multiple sources were used to undertake a review of literature up to early 2019. These included the websites of local, state and federal government departments and road safety advocacy organisations in Australia, New Zealand and other countries for which English language documents were available. In addition, grey literature (primarily technical reports and conference papers) and published, peer-reviewed journal articles were sourced. They were obtained by searching Google Scholar, ResearchGate and various library databases. The search terms searched included combinations of the following: *"motorcycle", "moped", "motorcyclist"* and *"motorcycle rider"* together with *"risk factors", "crash risk", road safety", "safe system"* and *"infrastructure"*. Furthermore, publications of authors who had published widely in the area or had a significant publication relevant to the topic, and publications citing or cited by relevant articles were also reviewed for relevance.

2.3 Crash analysis data requirements

2.3.1 Crash Data

Crash data was requested for the period 1 January 2013 to 31 December 2017 for the whole of the state of WA. Crash data was extracted from the Integrated Road Information System (IRIS), which contains detailed information on the characteristics of the vehicles involved in road crashes, crash circumstances, police-reported injury and road information related to the crash location. The IRIS is maintained by Main Road Western Australia. Unit record information was required for each person involved in each crash, including: accident number; accident type; sex, age; road user type (e.g., motorcyclist); date, time, and location details (including geocoding data) of crash; all collected information on the nature and circumstance of crash; and the severity of the crash based on the most severe injury recorded for an involved road user. Crashes were flagged as involving motorcyclists, using the U-Type variables for motorcycle (value 8), trailbike (value 21) and moped (value 22). All reported crashes involving motorcycles were included in the analysis, including fatal, hospitalisation, medical treatment only and property damage only (PDO) crashes.

2.3.2 Map

A map was created using a geographic information system[6] (GIS - ArcGIS 10.6). In order to create a map in ArcGIS, various shapefiles[7], were required to create 'layers', including administrative boundaries, road network centrelines and the location of intersections. The ABS postal areas shapefile is freely available from the Australian Bureau of Statistics web-site. The road centrelines shapefile was acquired from Main Roads Western Australia. These two layers were used to create the base map. All crashes involving motorcyclists were plotted on the map.

2.4 Analysis

2.4.1 Statistical analysis

Crash data was summarised using frequencies of demographic characteristics of motorcyclists, crash type and characteristics, road characteristics and time of day. The number of motorcycle crashes per postcode was calculated. In addition, motorcycle crashes that occurred at intersections were identified: 3,392 motorcycle crashes occurred at intersection, 50.5% of 6,723 all crashes involving motorcyclists). Those intersections with five or more crashes between 2013 and 2017 were reported.

2.4.2 Spatial analysis

The map was used to guide further analysis of high- risk areas for motorcycle crashes. Because of the relatively low number of motorcycle crashes and the small high-risk areas examined, crash counts were not standardised by population, vehicle kilometres travelled or number of licensed vehicles.

Heat maps, which indicate areas of high and low density of crashes, were created of Perth and the rest of WA. The choice of the parameters used to create the maps was guided by the literature relating to the use of heat maps in road safety research (Anderson, 2007, Anderson, 2009, Thakali et al., 2015). Because of the large area of regional and remote WA and geographically diverse spread of crashes, the heat map of the rest of WA was not useful in identifying high risk sections of the road network in regional and remote WA.

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[6] A GIS is defined as *'a constellation of hardware and software that integrates computer graphics with a relational database for the purpose of managing data about geographic locations'* RIPPLE, W. J. 1989. *Fundamentals of Geographic Information Systems : a Compendium* Bethesda, Md., American Congress on Surveying and Mapping

[7] A shapefile is a geospatial data format used for geographic information system (GIS) software.

Furthermore, each crash was spatially joined to the relevant road section (using the network element identifier, the IRIS unique network element identifier variable) in ArcGIS. Any road segments with one or more motorcycle crashes were identified. Road sections with eight or more motorcycle crashes were reported.

Because heat maps did not provide a helpful assessment of motorcycle crashes in regional and remote areas, the previously calculated number of crashes per postcode in regional and remote areas were used to identify the postcodes with the highest number of motorcycle crashes. The five postcodes in regional and remote WA with the highest number of motorcycle crashes over the study period were identified and the pattern of the crashes was examined for each of these postcodes, by creating individual maps of the high crash count postcodes that included the crash locations and road network.

2.4.3 Virtual inspections of high motorcycle crash areas

Virtual inspections were undertaken using the Main Roads Road Information Mapping System (Main Roads Western Australia, 2019a), Nearmap (Nearmap Ltd., 2016) and Google Maps of areas with clusters of motorcycle crashes. This included examining the characteristics of the routes such as the number of lanes, any intersections present, traffic control types and any changes over time. This was done for the top three intersections (nine or more motorcycle crashes) and road segments with 11 or more motorcycle crashes in the metropolitan area. The five regional and remote postcodes with the highest number of motorcycle crashes over the study period were also inspected. The characteristics of individual crashes in these high-risk areas were also examined for patterns. Action 34 of the Motorcycle Strategic Plan, on which this project is based was to "Assess a small number of popular routes using a skilled and experienced rider communicating to a following vehicle, to identify the potential for a mass action treatment of issues." The use of virtual inspections enabled the analysis of a much larger area (the whole of the state) and the examination of a larger number high risk areas within the state in a cost- and time-effective manner.

2.5 Ethics approval

Ethics approval was obtained from the Curtin Human Research Ethics Committee. Approval was granted on 23 August 2018. The approval number for the project is HRE2018-0547.

3 LITERATURE REVIEW

Motorcycles have become an increasingly popular form of transport. According to the Australian Bureau of Statistics 2018 Motor Vehicle Census, motorcycle registrations have grown from 113,852 in 2013 to 127,859 in 2017 and 125,647 in 2018 in WA. In Australia overall, the number of motorcycle has grown from 744,732 in 2013 to 849,265 in 2017 and 860,700 in 2018 (ABS, 2018).

Motorcycles have several advantages over cars; they are efficient in congested areas, require less space to park than cars, have lower running costs (fuel and maintenance), and have a lower impact on the environment (EuroRAP, 2008). They provide an alternative to public transport, allowing longer distances to be travelled than if walking and cycling (EuroRAP, 2008). In addition to lower costs and the practical benefits of using a motorcycle, motorcycles are also used for leisure and recreation ('adventure') (BITRE, 2017a).

Subtypes of motorcycles are: i) a scooter which has a step-through frame and a foot platform or integrated footrests; and ii) a moped which is a motorcycle with a maximum speed of 50km/h and an engine capacity of no more than 50cc (that is, cubic centimetres of displacement, a measure of engine size) (Department of Planning Transport and Infrastructure, 2017).

Australian statistics show that there were 248 motorcycle fatalities in Australia in 2016 (BITRE, 2017a) of which 240 were motorcyclists and eight were pillion passengers. These accounted for nearly one in five road deaths in 2016. A total of 93% of these were male and the mean age has increased from 36 years in 2006 to 40 years in 2016 (BITRE, 2017a). Motorcycle crashes peak between 9am and 9pm on weekdays, and one third of these crashes occurring between 9am on Saturday and 3pm on Sunday.

The vulnerability of motorcyclists is due to a number of contributory factors: characteristics of motorcycle, the environment, and behavioural factors. Motorcycles, as two wheel vehicles with a relatively high power-to-weight ratio, are inherently less stable and more difficult to control, and provide little physical protection to motorcycle rider in a crash. They can easily become unstable; if the breaks are not applied correctly, skidding and a loss of control may occur. The high power-to-weight ratio means that motorcycles can accelerate quickly and reach high speeds (Elliott, Armitage, & Baughan, 2003). Operating a motorcycle is more complex than driving a car, requiring excellent coordination, balance, and motor skills (Houston, 2011)

3.1 Factors which affect motorcycle crashes

3.1.1 Demographic factors

Gender

Data for the whole of Australia demonstrated that 93% (n=226) of all motorcycle fatalities in 2016 were males (BITRE, 2017a). This is similar to motorcycle fatalities reported for the period 2001 to 2006 in Australia, where 95% of the 1,323 motorcycle fatalities were male (Bambach et al., 2012).

Male motorcyclists predominant in motorcycle fatalities in other countries, including Malaysia where 94% (3,664) of 3,898 fatalities in 2008 were male (Abdul Manan and Várhelyi, 2012). Research in the UK found that 90% (1,120) of 1,239 admitted because of a motorcycle crash were male (Ankarath et al., 2002). A case-control study of 352,177 motorcycle and moped in France showed that male motorcyclists were at higher risk of crash than female motorcyclists (Moskal et al., 2012).

Age

Higher risk of motorcycle crashes has shifted to older motorcyclists, aged 40 years and older (BITRE, 2017b) with this being the fastest growing group involved in fatal motorcycle crashes in the US (Lin and Kraus, 2009). The mean age of motorcycle fatalities has risen over the last decade to 40 years old in 2016 (BITRE, 2017a). Notably, more deaths in motorcyclists under 40 years occurred in urban areas, while deaths in those over 40 years tended to occur in regional and remote areas (BITRE, 2017a). Although it is unclear from the data, this may relate to different patterns of motorcycle use in metropolitan compared to regional and remote areas, for example, the proportion commuting vs recreational riding.

A case-series study of 235 injured motorcyclists in Victoria found that, for every 10 year increase in rider age, there was a 38% decrease in rider error being judged as the primary contributory factor to multi-vehicle motorcycle crashes (Allen et al., 2017).

A case-control study in France found that for both moped and motorcycle crashes, youngest (under 16 year olds) and oldest (over 65 years) motorcyclists were most at risk of crash (Moskal et al., 2012). Research in Sweden followed 334,070 young people aged 16 to 25 years old, including 2,034 motorcyclists involved in injury crashes (Zambon and Hasselberg, 2006b). The study found significant differences in the incidence and severity of injury by socioeconomic status, especially in the 17 to 19 year old age group (Zambon and Hasselberg, 2006b). Incidence was highest and injuries more likely to be severe among those in lower socioeconomic groups.

3.1.2 Motorcycle skill- and vehicle-related factors

Licence status

Research has found that the risk of crash and serious injury is higher among motorcyclists who ride without a licence (Dandona et al., 2006, Lin and Kraus, 2009, Abdul Manan and Várhelyi, 2012). The large case-control study in France found that motorcyclists without a license had twice the risk of been involved in a crash than those with a licence (Moskal et al., 2012).

Experience and training

Research has shown that lower experience in riding is associated with higher risk of motorcycle crash and higher injury risk (Lin et al., 2003, Wali et al., 2018), while crash risk reduced with increasing number of years with a licence (Moskal et al., 2012). Higher number of kilometres travelled was associated with higher risk of motorcycle crash , probably due to increased exposure to traffic (Wali et al., 2018).

A review of the literature up to 2009 found that motorcyclists who had formal motorcycle rider training did not have significantly lower risk of crash, of traffic violations or of cost of medical treatment than motorcyclists who were untrained (Lin and Kraus, 2009). A randomised control trial was conducted in Victoria, Australia between 2010 and 2012 (Ivers et al., 2016). Those in the intervention group were involved in a program including pre-program activities, four hours of driving and a facilitated small group discussion with a riding coach. There was no significant difference in crash risk between the intervention and control groups at three and twelve months after the program. More recently, however, Wali and colleagues found that those who had completed approved entry-level driving courses and had received formal training after the year 2000 were less likely to crash compared with those who had not received this training (Wali et al., 2018).

Ownership of motorcycle

Multiple studies have found that crashes are more likely to occur to motorcyclists who do not own the motorcycle they are riding, than to owners of their motorcycles (Lin and Kraus, 2009). Motorcyclists riding an unfamiliar motorcycle were more likely to be involved in a crash than other motorcyclists (Brown et al., 2015).

Motorcycle trip and type

Motorcyclists using a sports motorcycle had higher odds of more serious injury crashes than motorcyclists using other motorcycle types. This association was stronger among older motorcyclists (Brown et al., 2015).

Few studies have examined injury and crash risk separately for moped and motorcyclists. However, Moskal and colleagues, in a national study in France found that the presence of a passenger was associated with increased risk of being responsible for the crash among moped, but decreased risk of being responsible for the crash among motorcycle crashes (Moskal et al., 2012).

3.1.3 Risk-taking behaviour

The six-year analysis of fatal motorcycle crashes in Australia found that some form of risky riding behaviour was identified as a contributory factor among half (n=663) of fatalities (Bambach et al., 2012). The risk behaviours included excessive speed, alcohol, drugs and disobeying a traffic control law. These behaviours were significantly associated with the following: males, under 35 years old, riding in the evening on weekends, suburban areas, unregistered motorcycles and single vehicle crashes (Bambach et al., 2012).

Crash risk can also be increased by carelessness, inattention and negligence (Blackman et al., 2009). A less frequent contributory factor is a medical condition (Blackman et al., 2009). A study in Singapore using data from 27,570 motorcycle crashes, found that being ‘at fault’ for a crash was associated with more severe injuries (Quddus et al., 2002).

Fatigue is a further risk for motorcycle crashes, and can lead to poor attention, slowed reaction times, impaired judgement and risk of falling asleep (Vlahogianni et al., 2012). The additional physical effort required to control the motorcycle and concentrate more on the road surface increases the likelihood of fatigue among motorcyclists (Vlahogianni et al., 2012).

High speeds

Higher riding speed is a common contributory factor to motorcycle crashes (Preusser et al., 1995, Jones et al., 2013) and is associated with more serious injuries than crashes occurring at lower speeds (Lin and Kraus, 2009). Jones and colleagues have shown that increasing speeding is associated with increasingly severe motorcycle crashes (Jones et al., 2013). A total of 35

(28%) of fatal and serious injury motorcycle crashes in South Australia (2012-2016) were on roads with speed limits of 100km/h or above (Department of Planning Transport and Infrastructure, 2017).

High speeds, and other risk-taking behaviours, are more common among younger motorcyclists (Lin and Kraus, 2009). In a case series study in Victoria, inappropriate speed (as judged from an in-depth crash investigation) was associated with other rider errors, such as rider misjudgement or control errors (Allen et al., 2017).

Alcohol and illicit drugs

As in crashes involving only motor vehicles, alcohol has been found to be a major contributor to both non-fatal and fatal motorcycle crashes (Preusser et al., 1995, Lin and Kraus, 2009, Jones et al., 2013). The 2011 Australian Burden of Disease found that alcohol use was responsible for 30% of the burden of road traffic injuries involving motor vehicle occupants and 33% of the burden for motorcyclists (AIHW, 2018). Motorcyclists are more vulnerable than other motor vehicle drivers to alcohol's effects particularly to balance and motor co-ordination, as a two-wheeler vehicle is inherently less stable than a motor vehicle with four wheels (Lin and Kraus, 2009).

A Thai study, which included 969 crashes involving 1,082 motorcyclists, found that 393 (36%) motorcyclists had been drinking prior to the crash (Kasantikul et al., 2005). The study showed that alcohol-related motorcycle crashes were more likely to involve loss of control (usually run-off road crashes), single vehicles, violation of traffic control signals, inattention, male motorcyclists, at-fault motorcyclists and result in hospitalisation (Kasantikul et al., 2005). The records of 1,748 Swedish motorcyclists aged 16 to 30 years who had sustained an injury were analysed (Zambon and Hasselberg, 2006a). The study found that positive suspicion of alcohol use was the strongest predictor of a severe injury (Zambon and Hasselberg, 2006a), compared with driving in a rural area and riding in an area with a posted speed limit of above 50km/h.

Other drugs, including prescription drugs such as benzodiazepines, and illicit drugs such as marijuana and cocaine, have frequently been used, often with alcohol, among motorcyclists involved in motorcycle crashes (Lin and Kraus, 2009). It is estimated that the use of illicit drugs is responsible for 5.2% of the burden of road traffic injuries involving both motor vehicle motorcyclists (AIHW, 2018). Nearly a quarter (n=32) of motorcyclists killed in crashes in South

Australia between 2012 and 2016 tested positive to the drugs cannabis, ecstasy or methamphetamines, singly or in combination (Department of Planning Transport and Infrastructure, 2017). An analysis of fatal motorcycle crashes between 2001 and 2006 across Australia found that 207 (27%) cases with toxicology reports had used illicit drugs, 233 (30%) had consumed alcohol and 359 (47%) had consumed either alcohol or drugs, or both prior to the crash (Bambach et al., 2012).

3.1.4 Time of day, weather and road conditions

National data in Australia shows that motorcycle fatalities peak between 9am and 9pm, with a third of all crashes occurring between 9am on Saturday and 9pm on Sunday (BITRE, 2017b). A study using Australian national motorcycle fatality data showed that most fatal crashes occurred between Friday and Sunday. The majority of fatal crashes occurred between noon and 8pm (throughout the week, Bambach et al., 2012). A study of 4,729 college students in Taiwan that found that crashes that occurred in the dark were associated with more severe injuries (Lin et al., 2003). Research in Malaysia found that single vehicle fatal motorcycle crashes were more likely to occur between midnight and 6am, than fatal motorcycle crashes involving two vehicles (Abdul Manan et al., 2017).

Cheng and colleagues used six years of data from San Francisco to examine the effect of weather on motorcycle crashes. They studied: 2,141 injured motorcyclists between 2008 and 2013 (Cheng et al., 2017). The study, which used a full Bayesian approach, included mean temperature, humidity, precipitation, cloud cover and day of the week. It found that as mean temperature increased, the number of fatal crashes increased while the number of less severe crashes decreased. As rainfall increased, motorcycle crashes of all severities decreased (Cheng et al., 2017). This concurs with research in other countries, which found that the majority of motorcycle crashes occur in dry conditions (Department of Planning Transport and Infrastructure, 2017, Vlahogianni et al., 2012). National fatality data demonstrated that 66% of 273 known fatal crashes (2001-2006) where weather data was available, occurred in fine, dry conditions on a dry road surface (Bambach et al., 2012).

3.1.5 Crash location and crash type

A study conducted in Western Australia, using police-reported serious motor vehicle crashes between 2005 and 2009, included 2,034 motorcycle crashes (Palamara et al., 2013). The authors found that motorcycle crashes were more often involved in multiple vehicle crashes in metropolitan areas and single vehicle crashes in regional and remote Western Australia. More than a third of fatal crashes occurred on regional and remote roads (Palamara et al., 2013) and a higher proportion of these crashes occur over the weekend (BITRE, 2017a). A study in north Queensland used data on motorcycle crashes resulting in hospitalisation and death between 2004 and 2008 {Blackman, 2009 #2890. The study found that, of 23 deaths, half (n=11) were single vehicle crashes.

National statistics from 2013 to 2015 demonstrated that less than half of motorcycles crashes involved a single vehicle; 65% of single vehicle fatal motorcycle crashes involved a non-collision on a curve, with 27% involving a non-collision on the straight (BITRE, 2017a). A total of 47% of single vehicle non-fatal injury crashes were non-collision crashes on the straight with 39% being on a curve (BITRE, 2017a).

Of fatal motorcycle crashes involving two vehicles, 39% involved vehicles from opposing directions (either head-on or right thru), while 19% were in adjacent directions (either right near or cross traffic). One-third of non-fatal injury crashes involving two vehicles were in the same direction (rear-end, sideswipe or turning sideswipe), while 22% were in opposing directions (right thru, head on and right/left crashes) (BITRE, 2017a).

Similarly, national motorcycle fatality data from 2001 to 2006 found that 630 (56%) were multi-vehicle crashes and 497 (44%) were single vehicle crashes (Bambach et al., 2012). The authors found that nearly half of multi-vehicle motorcycle crashes occurred at intersections (47%), two-thirds of these when a vehicle turned in front of a motorcyclist (Bambach et al., 2012).

International research has found that severe and fatal motorcycle crashes are more likely to occur at intersections than at other locations (Vlahogianni et al., 2012), with right-of-way violations representing the most common type of crash. An older US study used 2,074 fatal motorcycle crashes (Preusser et al., 1995) to identify five crash types: run-off road, ran traffic control, head-on, left-turning oncoming (right-turning in Australia), and motorcyclist down. Nearly half (41%) of the crashes were run-off road motorcycle crashes (and therefore single vehicle crashes) (Preusser et al., 1995). A recent study in Malaysia of motorcycle crashes involving 9,176 fatalities demonstrated that road curves, no road markings, smooth, rutted and corrugated road surfaces were associated with higher probabilities of single vehicle fatal motorcycle crashes (Abdul Manan et al., 2017). Motorcycle crash risk is affected by bridges, with an increased risk of a crash when bridges are on curves or lower friction surfaces (Vlahogianni et al., 2012).

3.1.6 Conspicuity

A literature review of motorcycle right-of-way crashes (Pai, 2011) found the two major causes of this crash type were lack of motorcycle and rider conspicuity and motorists' speed/distance judgement errors. The review further found that, although conspicuity aids help, brightness contrast between the motorcycle and rider, and the surroundings may be more important than objective brightness (Pai, 2011).

Studies have found that poor visibility and darkness are associated with greater motorcycle injury severity, both because of the motorcyclists' ability to see and be seen (Vlahogianni et al., 2012). Conspicuity has two aspects: the visibility of the motorcycle itself, and of the rider of the motorcycle. Interventions to improve the conspicuity of the motorcycle include using daytime headlights (Davoodi and Hossayni, 2015).

Clothing which increases conspicuity, such as reflective vests and other high visibility clothing, can also be used. A New Zealand study with 463 motorcycles involved in crashes leading to hospitalisation or death, compared with 1,233 motorcyclists surveyed at the roadside, investigated the association between crash risk and conspicuity of the rider or vehicle (Wells et al., 2004). The study found that motorcyclists wearing any reflective or fluorescent clothing had a 39% lower risk of injury. Wearing a white helmet (compared to a black helmet) was associated with a 24% lower risk. However, the frontal colour of clothing of either rider or of the motorcycle was not associated with injury risk (Wells et al., 2004). Further, Wali and colleagues found that motorcyclists wearing red upper body clothing (indicating lower conspicuity) were significantly more likely to be involved in crashes (Wali et al., 2018).

3.1.7 Motorcycle safety features

In recent years, safety features are being developed which can protect the motorcyclist both from a crash and reduce the severity of a crash. These include:

v) Airbags;

vi) Motorcycle Stability Control (MSC – which stops brakes locking under heavy breaking, stops wheels spinning under accelerating and stops the rear or front wheel from lifting);

vii) Linked Braking System (LBS – which distribute the braking force between the front and rear braking systems) which can be combined with the Anti-lock Braking System (ABS); and

viii) Electronic Control Unit (ECU) to ensure that traction with the road is maintained (VicRoads, 2015).

A study conducted using Australian crash data found that the presence of ABS on a motorcycle was associated with a 33% reduction in all injuries and 39% reduction in severe injuries in crash types where ABS was likely to be beneficial (Fildes et al., 2015).

An online survey was conducted by the RAC in Western Australia in mid-2016, including a convenience sample of 2,317 motorcyclists and 424 drivers aged 18 years and older (RAC, 2018). Nearly all (99%) of the motorcyclists surveyed always wore a helmet and more than 90% usually wore gloves or a motorcycle jacket. A total of 43% of those motorcyclists surveyed had ABS and 58% had automatic headlights (RAC, 2018).

3.1.8 Use of helmets

Research from the UK showed that those wearing a helmet had significantly less severe head injuries (as indicated by a higher Glasgow Coma Scale or GCS) than those who did not use a helmet (Ankarath et al., 2002). While the three types of helmets – full-face, full-coverage and half-coverage – have been found to reduce head injuries, differences in the effectiveness between helmet type have not been examined (Lin and Kraus, 2009). However, a more recent in-depth study conducted in New South Wales, consisting of 98 seriously injured and 10 fatally injured motorcyclists, found that full face helmets provided better protection than open face helmets (Brown et al., 2015).

A Cochrane review of the use of helmets to prevent injury in motorcycle injury (Liu et al., 2008) reviewed randomised control trials, non-randomised control trials, cohort, case-control and cross-sectional studies. The review found evidence that helmets reduce risk of death by 42% and reduced risk of head injury by 69% (Liu et al., 2008).

An systematic review of twelve economic analyses between 1994 and 2014 found that motorcyclists admitted to hospital after crashing while not using a helmet had acute hospital costs of UD$12,239 more than motorcyclists admitted after crashing while using a helmet (Kim et al., 2015). Injured motorcyclists who used helmets had lower injury severity than those who did not use helmets.

3.1.9 Use of protective clothing

An in-depth motorcycle crash study of 102 Australian motorcyclists found that motorcyclists wearing more protective clothing were less likely to be involved in crashes (Brown et al., 2015). Protective clothing can reduce the severity of an injury to a motorcyclist involved in a crash (de Rome et al., 2014). These include footwear, long- and short-sleeve tops and pants, and gloves (de Rome et al., 2014). Research in the ACT examined 202 motorcyclists who had been involved in a crash and treated at a hospital emergency department. The research found that motorcyclists wearing clothing that fully covered their body had a significantly reduced risk of an injury, compared to motorcyclists wearing garments covering only part of the body (for example, long- versus short-sleeved tops), and that skin coverage was more important than fabric type (de Rome et al., 2014). Those motorcyclists wearing motorcycle jackets, pants or gloves were significantly less likely to be admitted to hospital (de Rome et al., 2011).

3.1.10 Road design and infrastructure, including crash barriers

Although road infrastructure should be designed to accommodate every road user (BITRE, 2017a), roads tend to be designed around the needs of motor vehicles, rather than motorcycles and other vulnerable road users. Road features which impact on motorcyclists include slippery road surfaces, manhole covers without skid resistance treatment, intersection design, signage, pole locations and crash barriers (Vlahogianni et al., 2012, BITRE, 2017a).

Research has shown that hitting a roadside safety barrier (guard rail) can affect the severity of the injury, and injuries may be more severe from hitting this barrier than what the barrier was protecting the rider from (EuroRAP, 2008). It is acknowledged that guardrails are designed to protect motor vehicle occupants, rather than motorcyclists and fatality risk is higher when a motorcyclist hits a guard rail (EuroRAP, 2008). There are three main types of guardrails: W-beam guard rails (Figure 1), concrete barriers (Figure 2) and wire rope barriers (Figure 3).

Figure 1: A W-Beam guard rail

Source: http://www.ingalcivil.com.au/products/road-safety-barriers/guardrail/flexbeam

Figure 2: A concrete safety barrier

Source: http://extrudakerb.com/

Figure 3: A wire rope barrier

Source: http://www.acprod.com.au/products/sentryline-ii-tl-3-and-tl-4-wire-rope-safety-barrier-system

There is concern that wire rope barriers do not protect motorcyclists as effectively as other road users, and may result in more severe injuries (BITRE, 2017a). European research has found increased fatalities for wire rope barriers compared to other barrier types (FEMA, 2012). However, it should be noted that the statistics cited related to England and Scotland, which have a very different road network, and relate to crashes occurring before 2006. Research using six years (2001 to 2006) in New Zealand and Australia (Grzebieta et al., 2010, Grzebieta et al., 2013) found that 78 out of 1,462 fatalities involved a roadside barrier. A total of 34 of these involved post impacts: three sign-posts at the top of concrete barriers, two wire-rope barriers and the remainder involved W-beam barriers. Of these, 19 motorcyclists were in the upright position as they crashed, 13 slid and 2 were ejected from their motorcycles. The mean distance motorcyclists travelled from impact with the barrier was 21.8 metres (Grzebieta et al., 2013). They found that more fatalities occurred a following crashes with W-beam and concrete barriers. Further, a higher proportion of fatalities (relative to the proportion of all safety barriers) involved W-beams than wire ropes (Grzebieta et al., 2010).

Adaptations can be made to make guard rails safer for motorcyclists in the event of a crash. Milling and colleagues discuss motorcyclist-friendly crash barriers such as the use of flexible fabric mesh on existing barriers and retrofitting under-run protection to w-beam barriers. Other potential improvements include installing energy dissipaters on poles and posts, and ensuring that roadside objects such as trees, signs and poles are relocated to safer positions (Milling et al., 2016). Road safety barrier treatments have been successfully trialled on two roads in the Adelaide Hills in South Australia (Anderson et al., 2012).

3.2 Conclusion

This review of the literature has found that there are multiple individual demographic and behaviour factors, as well road-related and environmental factors which increase the risk of a motorcycle crash.

4 RESULTS

4.1 Overview

A total of 6,723 crashes involving motorcycles[8] occurred in WA between 2013 and 2017. This included 13,734 persons in all vehicles involved in crashes with a motorcycle and 7,231 persons either riding or a passenger of a motorcycle. Of those with age and sex recorded, the highest proportion of motorcyclists and passengers were between 16 and 24 years old (n=1,204, 22% - Table 1 and Figure 4)[9]. The age-groups 30 to 39 years (n=1,086), and 40 to 49 years (n=1,128) each made up 20% of those involved in motorcycle crashes. In contrast, all WA crashes from 2008 to 2017 had a higher proportion of those in their 30s (27%) and 40s (approximately 28%).

Males made up 87% (n=4,853) of those on motorcycles involved in crashes. This is considerably higher than the overall proportion of males (56%) involved in all crashes in WA between 2008 and 2017. The highest proportion of males was in the age-group 16 to 24 years old (n=1,028, 21%). A total of 41% (n=1,957) were aged between 30 and 49 years old. Only 702 (13%) were females. Of these, a quarter (n=176) were aged 16 to 24 years. Only 34 (4.8%) females were aged 60 years and above.

Table 1: Persons involved in motorcycle crashes by age and sex between 2013 and 2017, in WA

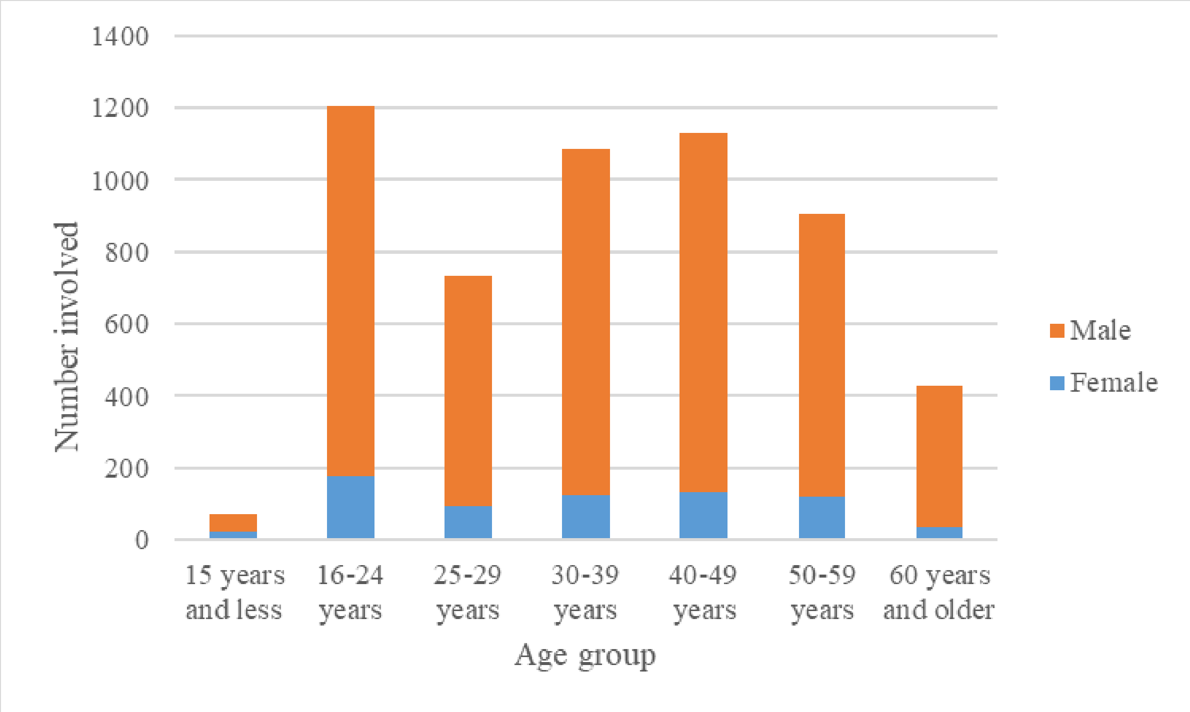
Sex	Female n (%)	Male n (%)	Total[1] n (%)
15 years and less	21 (3.0)	48 (0.99)	69 (1.2)
16-24 years	176 (25)	1,028 (21)	1,204 (22)
25-29 years	95 (14)	639 (13)	734 (13)
30-39 years	124 (18)	962 (20)	1,086 (20)
40-49 years	133 (19)	995 (21)	1,128 (20)
50-59 years	119 (17)	787 (16)	906 (16)
60 years and older	34 (4.8)	394 (8.1)	428 (7.7)
Total	702 (100)	4,853 (100)	5,555 (100)

[1]Total includes all persons involved in crashes with age reported

[8] The term 'motorcycle' includes motorcycles, mopeds and scooters, unless otherwise specified.

[9] All totals include both motorcyclists and their passengers as the road user was only reported for 6,771 of the 7,231 persons on motorcycles involved in crashes (see Table 7).

Figure 4: Persons involved in motorcycle crashes by age and sex between 2013 and 2017, in WA



Of those involved in crashes on a motorcycle with a recorded injury (n=3,258, 45% of persons on a motorcycle involved in a crash), 161 (4.9%) were fatally injured (Table 2). More than half (n=1,735, 53%) of those with recorded injuries required admission to hospital for treatment of their injuries.

Table 2: Persons involved in motorcycle crashes with a recorded injury, between 2013 and 2017, in WA

Severity of injury	**n (%)**
Death within 30 days of crash	161 (4.9)
Requiring admission to hospital	1,735 (53)
Requiring medical attention but not hospitalisation	1,240 (38)
Injury requiring no medical attention	122 (3.7)
Total	3,258 (100)

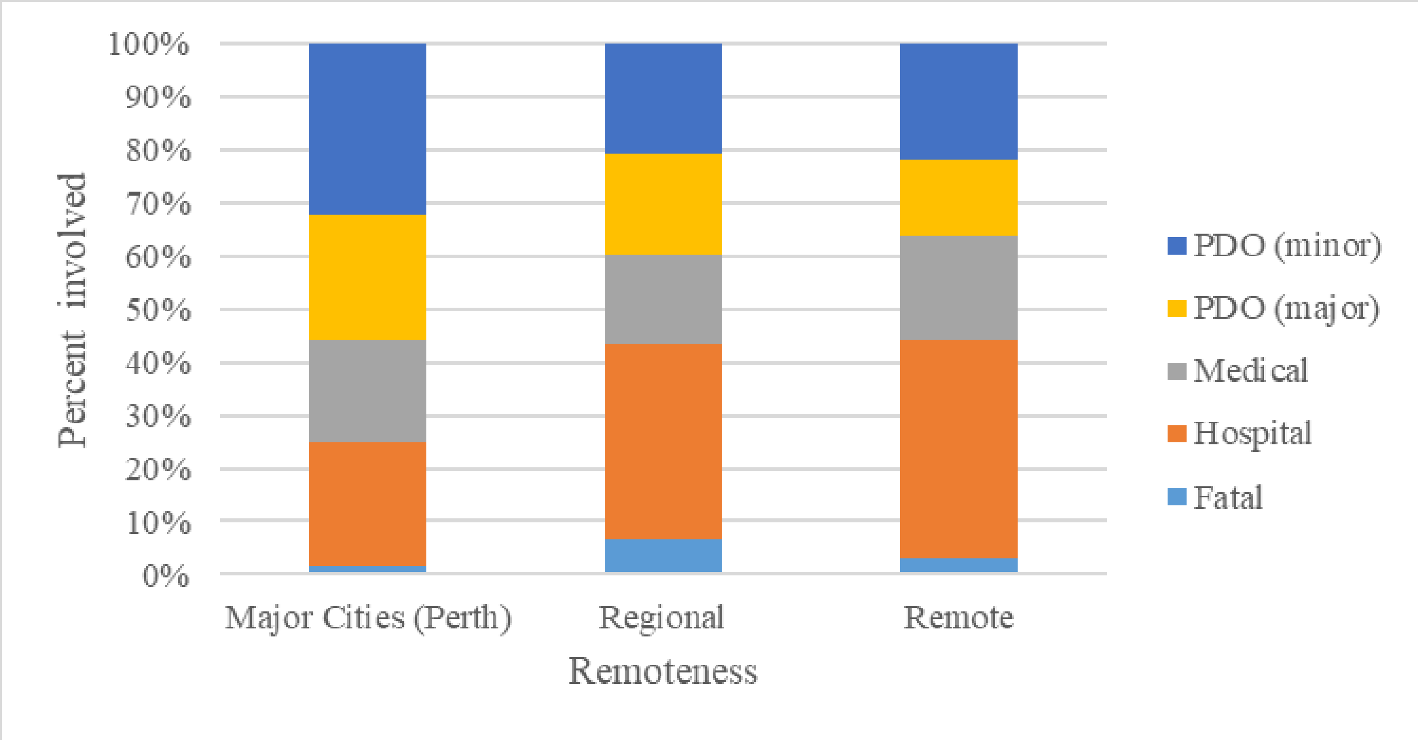
A total of 5,711 (80%) people were involved in motorcycle crashes which occurred in Perth metropolitan area between 2013 and 2017 (Table 3 and Figure 5). This compared to 610 (8.6%) in inner regional WA, 449 (6.3%) in outer regional WA, 264 (3.7%) in remote WA and 77 (1.1%) in very remote WA. Notably, a relatively higher proportion of fatal crashes occurred in inner and outer regional and remote WA, compared to in the Perth metropolitan area. In inner regional, which had 8.6% of all persons involved in motorcycle crashes, 25% (n=46) of all motorcycle fatalities in WA occurred. A relatively higher proportion of property only crashes occurred in Perth (n=3,188, 85%).

Table 3: Motorcycle crashes by remoteness and severity of crash, between 2013 and 2017

Remoteness	**Fatal n (%)**	**Hospital n (%)**	**Medical n (%)**	**Property damage only (major) n (%)**	**Property damage only (minor) n (%)**	**All crashes[1] n (%)**
Major cities (Perth)	101 (56)	1,320 (71)	1,102 (82)	1,338 (84)	1,850 (86)	5,711 (80)
Inner regional WA	46 (25)	239 (13)	106 (7.9)	107 (6.7)	112 (5.2)	610 (8.6)
Outer regional WA	24 (13)	151 (8.2)	73 (5.4)	94 (5.9)	107 (5.0)	449 (6.3)
Remote WA	8 (4.4)	102 (5.5)	55 (4.1)	39 (2.4)	60 (2.8)	264 (3.7)
Very remote WA	2 (1.1)	39 (2.1)	12 (0.89)	10 (0.63)	14 (0.65)	77 (1.1)
Total	181 (100)	1,851 (100)	1,348 (100)	1,588 (100)	2,143 (100)	7,111 (100)

[1]Includes all crashes with both postcode and severity of crash reported

Figure 5: Proportions of motorcycle crashes by remoteness and severity of crash, between 2013 and 2017



4.2 Motorcycle and licencing details

Of those involved in motorcycle crashes with licencing data recorded, the highest proportion of unlicenced motorcyclists was in the 25 to 29 year old age-group (n=165, 33%). More than two-thirds of motorcyclists were licenced among those aged over 30 years old. Most motorcyclists aged 60 and older (n=302, 91%) were licenced.

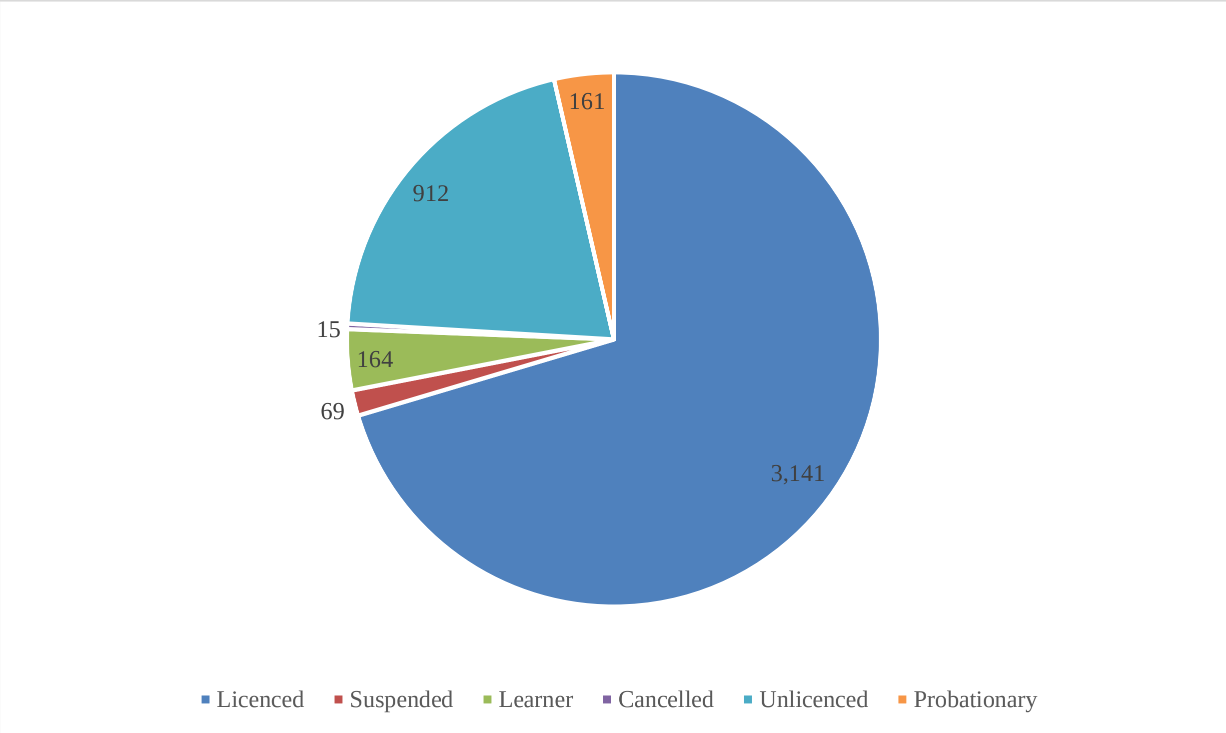
Table 4: Licence status of motorcyclists involved crashes, by age, between 2013 and 2017, in WA

Licence status	15 years and less n (%)	16-24 years n (%)	25-29 years n (%)	30-39 years n (%)	40-49 years n (%)	50-59 years n (%)	60 years and older n (%)	Total[1] n (%)
Licenced	0 (0)	365 (43)	305 (60)	561 (71)	679 (79)	592 (85)	302 (91)	3,141 (70)
Suspended	0 (0)	20 (2.4)	9 (1.8)	19 (2.4)	12 (1.4)	4 (0.57)	1 (0.30)	69 (1.6)
Learner	1 (4.0)	64 (7.5)	24 (4.8)	29 (3.7)	25 (2.9)	10 (1.4)	3 (0.90)	164 (3.7)
Cancelled	0 (0)	4 (0.47)	0 (0)	8 (1.0)	1 (0.12)	0 (0)	0 (0)	15 (0.34)
Unlicenced	24 (96)	246 (29)	165 (33)	175 (22)	146 (17)	90 (13)	27 (8.1)	912 (20)
Probationary	0 (0)	151 (18)	2 (0.4)	3 (0.38)	1 (0.12)	1 (0.14)	0 (0)	161 (3.6)
Total	25 (100)	850 (100)	505 (100)	795 (100)	864 (100)	697 (100)	333 (100)	4,462 (100)

[1]Total includes all motorcyclists involved in crashes with licence status and age reported

The licence status of all motorcyclists involved in crashes in shown in Figure 4 below. A total of 3,141 (70%) of crashes involved fully licenced motorcyclists.

Figure 6: Licence status of motorcyclists involved crashes (all ages) between 2013 and 2017, in WA



Almost all crashes involved motorcycles (n=6,933, 96%), with 3% (n=216) involving trailbikes and 1.1% (n=82) involving mopeds (Table 5).

Table 5: Type of motorcycle involved in crashes, between 2013 and 2017, in WA

Vehicle type	n (%)
Motorcycle	6,933 (96)
Trailbike	216 (3.0)
Moped	82 (1.1)
Total	7,231 (100)

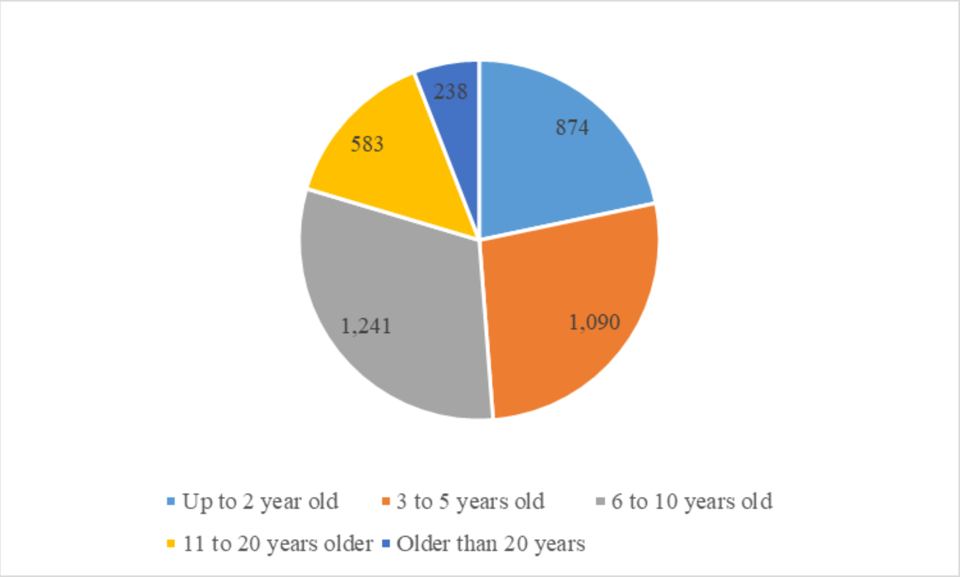
Nearly half of all crashes (n=1,865, 46%) involved motorcycles manufactured from 2010 onwards (Table 6). A total of 22% (n=874) motorcycles involved in crashes were two years old or less. Most motorcycles were 10 years old or less (n=3,205, 80% - Figure 7). Six (0.15%) of the motorcycles were 50 years or older.

Table 6: Motorcycles involved in crashes by year of manufacture, between 2013 and 2017, in WA

Year of manufacture	n (%)
Before 1990	124 (3.1)
1990 to 1999	307 (7.6)
2000 to 2004	371 (9.2)
2005 to 2009	1,359 (34)
2010 to 2014	1,823 (45)
2015 onwards	42 (1.0)
Total	4,026 (100)

[1]Total includes all motorcycles where year of manufacture was reported

Figure 7: Motorcycles involved in crashes by age of vehicle, between 2013 and 2017, in WA



The majority of persons with road user type recorded were motorcyclists (n=6,455, 95% - Table 7), while the remainder were pillion passengers. Most motorcyclists were male (n=5,816, 90%), while nearly two-thirds of pillion passengers (n=200, 63%) involved in crashes were female.

Table 7: Persons involved in motorcycle crashes by road user type and gender between 2013 and 2017, in WA

Road user	Female n (%)	Male n (%)	Total n (%)
Motorcyclist	639 (9.9)	5,816 (90)	6,455 (100)
Pillion passenger	200 (63)	116 (37)	316 (100)
Total	839 (12)	5,932 (88)	6,771 (100)

4.3 Time of crash

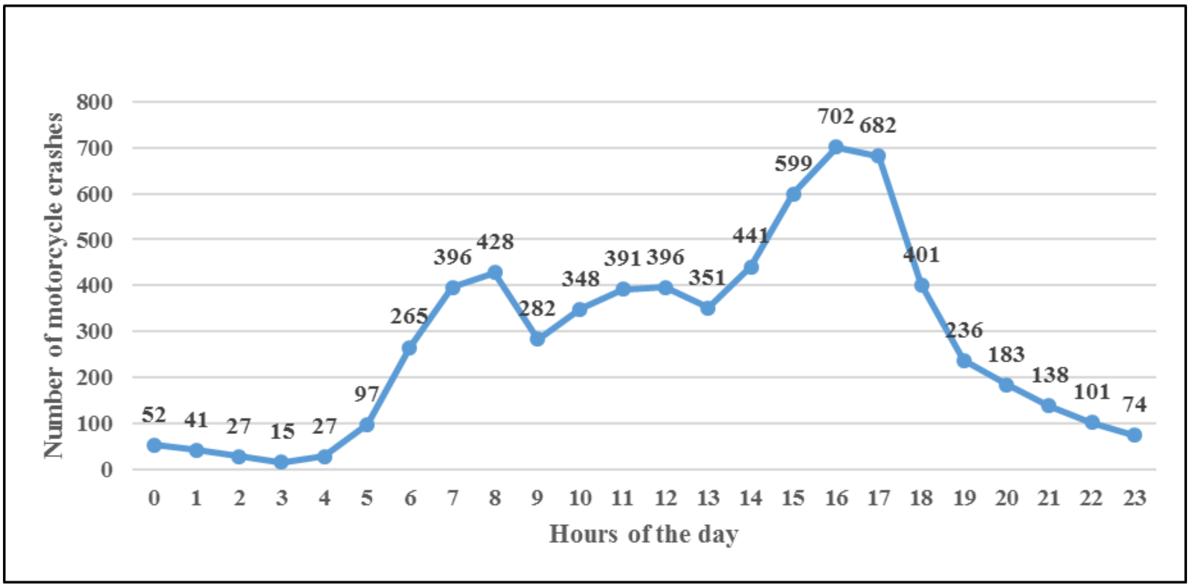
A higher proportion of crashes occurred between Tuesday and Friday, with Friday having the highest proportion of motorcycle crashes (n=1,125, 17% - Table 8).

Table 8: Crashes involving motorcycles by day of week, between 2013 and 2017, in WA

Crash count	n (%)
Sunday	826 (12)
Monday	810 (12)
Tuesday	988 (15)
Wednesday	996 (15)
Thursday	1,052 (16)
Friday	1,125 (17)
Saturday	926 (14)
Total	6,723 (100)

More motorcycle crashes occurred during the day, between 6am and 6pm (Figure 8). The peak in crashes occurred from 3pm up to 5:59pm. A peak of 702 (11%) crashes occurred between 4pm and 4:59pm.

Figure 8: Crashes involving motorcycles by hour of the day, between 2013 and 2017, in WA



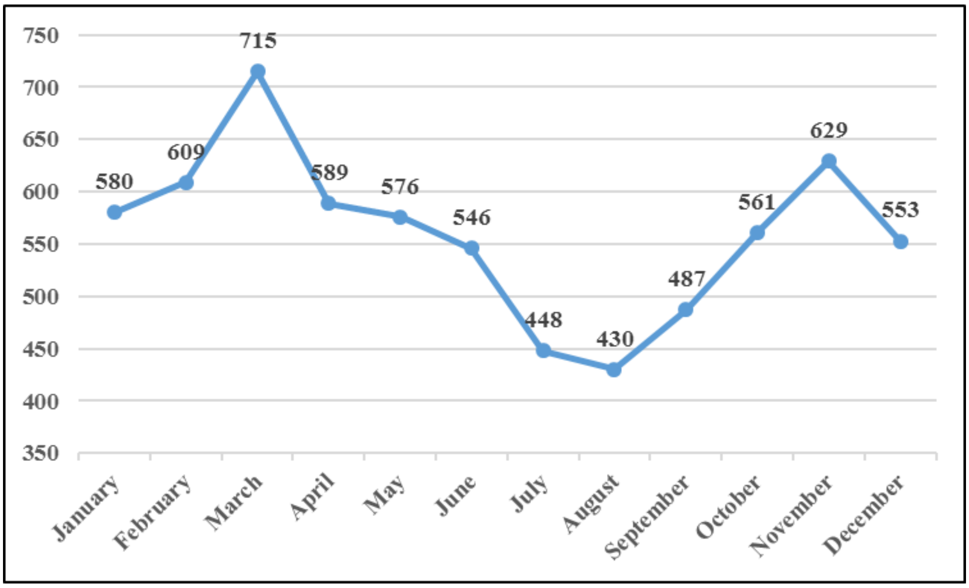
The highest number of crashes in the period between 2013 and 2017 occurred in 2013 (n=1,533, 23%), with the highest proportion of fatal crashes occurring in 2014 (n=44, 2.9% of crashes in that year) and 2016 (n=40, 3.3% of crashes in that year – Table 9).

Table 9: Crashes involving motorcycles by crash year and severity of crash, between 2013 and 2017, in WA

Crash year	Fatal n (%)	Hospital n (%)	Medical n (%)	Property damage only (major) n (%)	Property damage only (minor) n (%)	All crashes n (%)
2013	27 (1.7)	395 (26)	309 (20)	325 (21)	477 (31)	1,533 (23)
2014	44 (2.9)	343 (23)	300 (20)	331 (22)	489 (32)	1,507 (22)
2015	24 (1.8)	351 (26)	243 (18)	308 (23)	419 (31)	1,345 (20)
2016	40 (3.3)	293 (24)	207 (17)	295 (24)	373 (31)	1,208 (18)
2017	28 (2.5)	320 (28)	192 (17)	271 (24)	319 (28)	1,130 (17)
Total	163 (2.4)	1,702 (25)	1,251 (19)	1,530 (23)	2,077 (31)	6,723 (100)

The highest number of crashes occurred March (n=715, 11%), with the lowest number of crashes occurring in August (n=430, 6.4% - Figure 9).

Figure 9: Crashes involving motorcycles by month, between 2013 and 2017, in WA



4.4 Conditions of the road and environment

More than three-quarters of crashes occurred in the daylight hours (n=5,102, 77%), with 13% (n=879) of crashes occurring in the dark with street lights on (Table 10). Conditions were clear at the time of 86% (n=4,656) of the motorcycle crashes. A smaller proportion of motorcycle crashes occurred when it was overcast (n=421, 7.8%) or raining (n=287, 5.4%). Most motorcycle crashes occurred when the road was dry (n=5,115, 90%) and on sealed roads (n=6,504, 98%).

Table 10: Road and environmental conditions at the time of crashes involving motorcycles, between 2013 and 2017, in WA

Road and environmental conditions	n (%)
Light conditions	
Daylight	5,102 (77)
Dawn or dusk	438 (6.7)
Dark street lights on	879 (13)
Dark with street lights off	28 (0.43)
Dark with street lights not provided	139 (2.1)
Total	6,586 (100)
Atmospheric conditions	
Clear	4,656 (86)
Raining	287 (5.3)
Overcast	421 (7.8)
Fog or mist	23 (0.43)
Dust or smoke	13 (0.24)
Total	5,400 (100)
Road conditions	
Wet	567 (10)
Dry	5,115 (90)
Total	5,682 (100)
Road surface type	
Sealed	6,504 (98)
Unsealed	133 (2)
Total	6,637 (100)

4.5 Crash details

Most motorcycle crashes involved multiple vehicles (n=5,039, 75% - Table 11). Just over half of motorcycle crashes occurred at intersections (n=3,401, 51%) with most of the remainder occurring at midblock locations (n=3,274, 49%). Nearly a quarter of crashes were rear-end crashes (n=1,543, 24%), with 20% of crashes being right-angle crashes (n=1,275) and a further 20% being non-collisions (n=1,291). There were a total of 534 run-off road crashes (all 'hit object' or 'non-collision' crashes) and only 19 were reported as involving barriers or guard rails[10]. Nearly three-quarters of crashes occurred on a straight section of road (n=4,526, 76%) and most crashes occurred on a level stretch of road (n=4,460, 79%).

[10] The data on guard rail involvement comes from the three 'Object' fields. These fields were empty for most crashes so this may reflect under-reporting of guard rail involvement in motorcycle crashes.

Table 11: Crashes involving motorcycles by details of crash, between 2013 and 2017, in WA

Crash details	n (%)
Single or multiple vehicle crash	
Multiple vehicle crash	5,039 (75)
Single vehicle crash	1,684 (25)
Total	6,723 (100)
Crash type	
Midblock	3,274 (49)
Intersection	3,401 (51)
Parking area	2 (0.03)
Lane way	1 (0.01)
Recreation area	6 (0.09)
Roads open to public access	39 (0.58)
Total	6,723 (100)
Nature of crash	
Rear-end	1,543 (24)
Head on	77 (1.2)
Sideswipe same direction	1,000 (16)
Right-angle	1,275 (20)
Right turn thru	585 (9.1)
Hit pedestrian	56 (0.87)
Hit animal	93 (1.4)
Hit object[1]	522 (8.1)
Non-collision[1]	1,291 (20)
Total	6,442 (100)
Alignment	
Curve	1,550 (26)
Straight	4,526 (74)
Total	6,076 (100)
Grade of road	
Level	4,460 (79)
Crest of hill	126 (2.2)
Slope	1,039 (18)
Total	5,625 (100)

[1]There were 534 run-off road collisions (RUM codes 71-74 or 81-84), all of which were either 'hit object' or 'non-collision'.

4.6 High risk areas for motorcyclists in WA

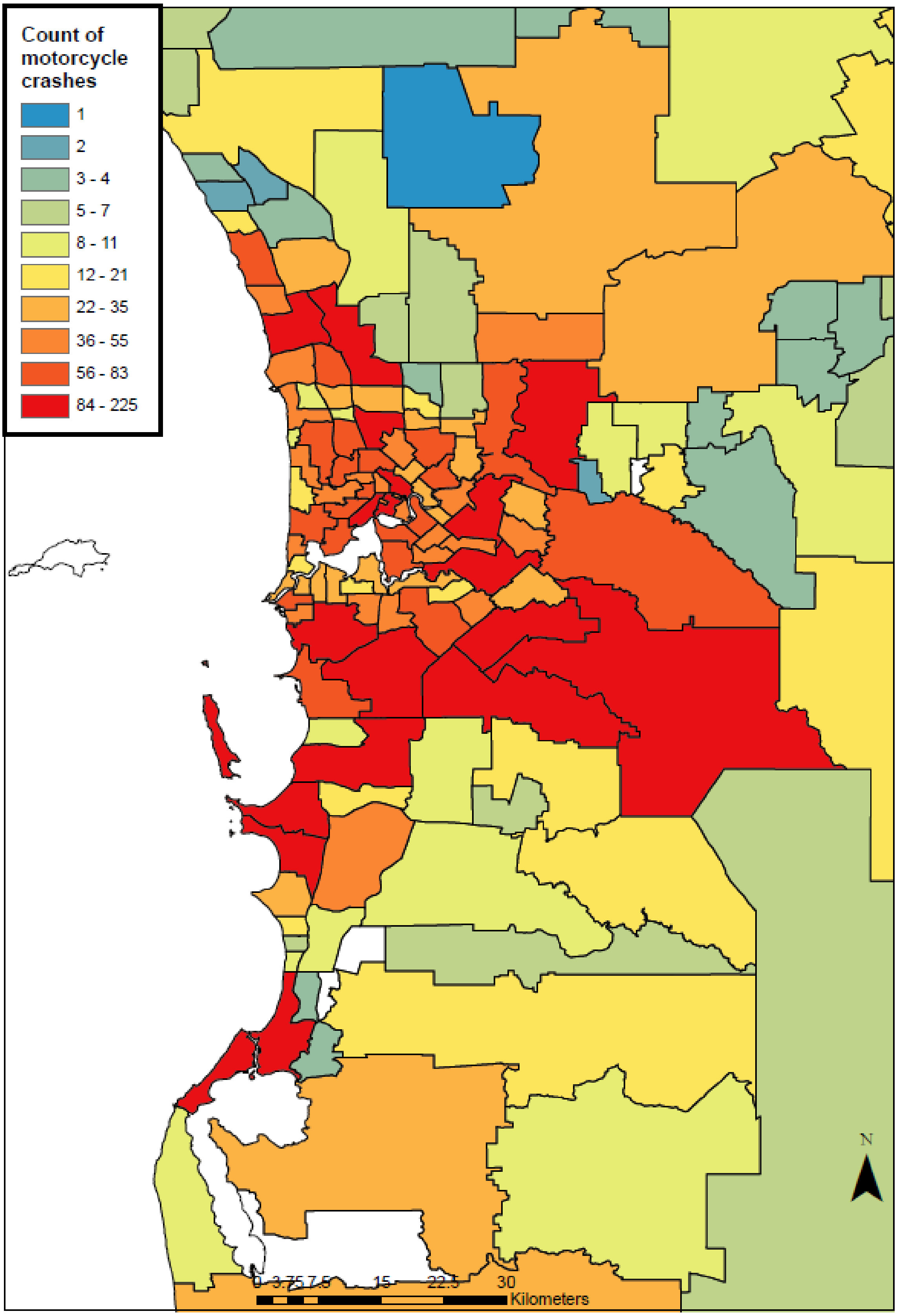
Postcodes with high numbers of motorcycle crashes were identified and a map was created indicating the distribution of motorcycle crashes by postcode in the Perth metropolitan area (Map 1). The postcode with the highest number of crashes in the metropolitan area (and the state) was Perth City, with 225 crashes in the five years between 2013 and 2017. There were 173 motorcycle crashes in postcode 6164 (including Jandakot, Cockburn, Hammond Park, Success, South Lake and Aubin Grove), and 168 crashes in postcode 6210 (Mandurah, Halls Head, Madora Bay and surrounding suburbs). Other postcodes with 100 or more crashes were postcodes 6112 (133 crashes), 6107 (133 crashes), 6163 (121 crashes), 6005 (120 crashes), 6056 (109 crashes), 6168 (107 crashes) and 6065 (100 crashes).

The postcodes with the highest number of fatal motorcycle crashes were postcodes 6112 (Armadale, Forrestdale and Seville Grove) and 6076 (Gooseberry Hill, Lesmurdie and Kalamunda): five fatal crashes each; and 6083 (Gidgegannup and Morangup) and 6155 (Willetton and Canning Vale): four fatal crashes each. Postcodes with three fatalities in the metropolitan area were: 6163 (Bibra Lake, Hilton, Kardinya); 6069 (Ellenbrook and Upper Swan); 6167 (Kwinana, Pamelia, Bertram); 6027; (Edgewater, Ocean Reef, Heathridge and Joondalup); 6111 (Kelmscott, Roleystone and Illawarra); 6166 (Coogee and Wattleup); 6020 (Carine, Marmion, North Beach and Sorrento); 6065 (Ashby, Darch, Wangara and Wanneroo); and 6210 (Mandurah, Halls Head, Madora Bay and surrounds).

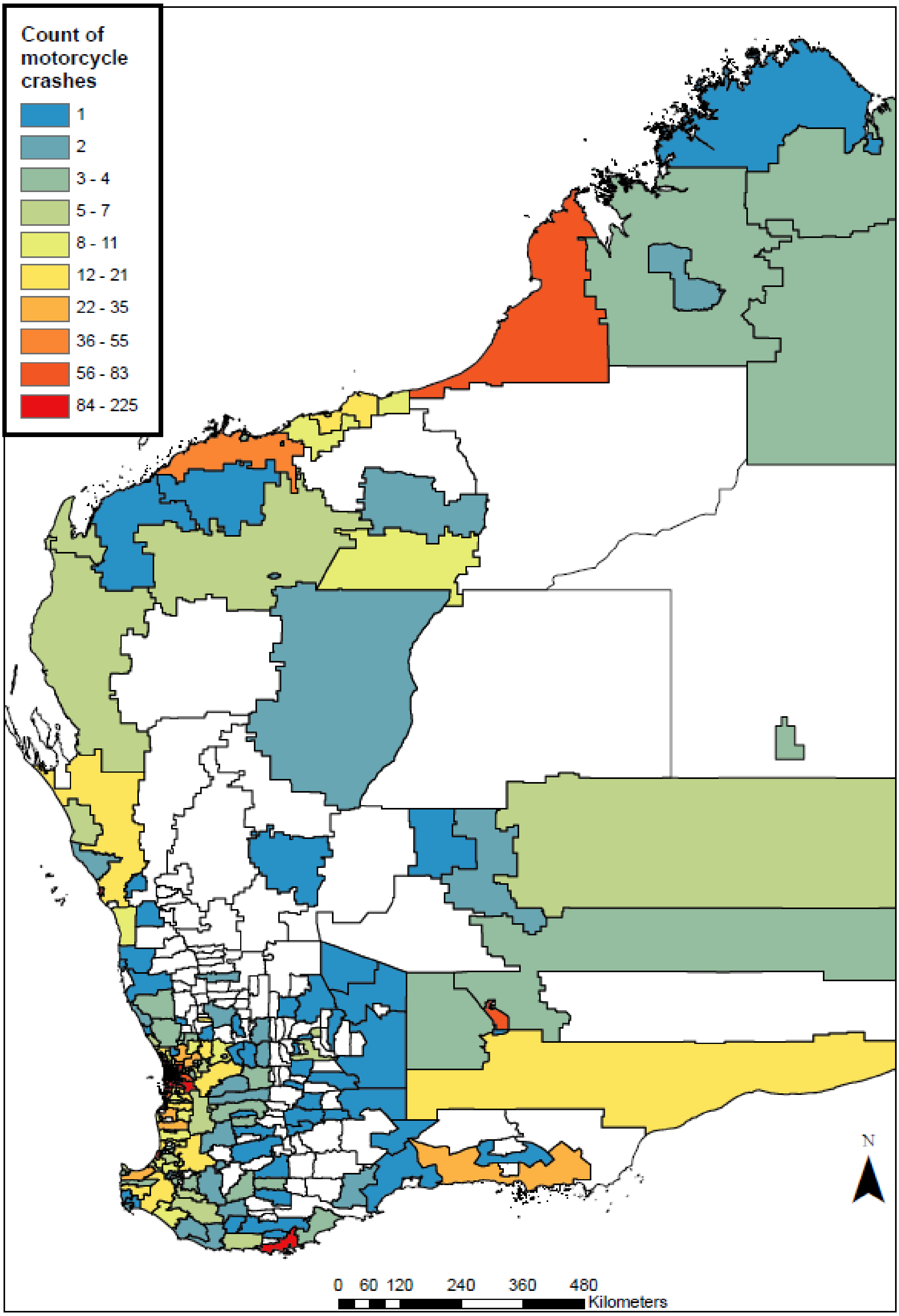
In regional and remote WA (Map 2), the postcode with the highest number of motorcycle crashes was 6230 (Bunbury and surrounds) with 115 motorcycle crashes between 2013 and 2017. Other regional and remote postcodes with high numbers of motorcycles were 6530 (Geraldton – 92 crashes), 6330 (Albany – 85 crashes), 6725 (Broome – 60 crashes), and 6430 (Kalgoorlie – 59 crashes).

Postcodes with four fatalities were 6230 (Bunbury) and 6330 (Albany). Those with three fatalities were 6443 (Balldonia, Eucla and Norseman); 6236 (Dardanup, Crooked Brook and Wellington Mill); 6566 (Toodyay, West Toodyay and Katrine) and 6225 (Collie, Shotts, Bowelling and Cardiff).

Map 1: Counts of motorcycle crashes per postcode between 2013 and 2017, in the Perth metropolitan area



Map 2: Counts of motorcycle crashes per postcode between 2008 and 2017, in WA

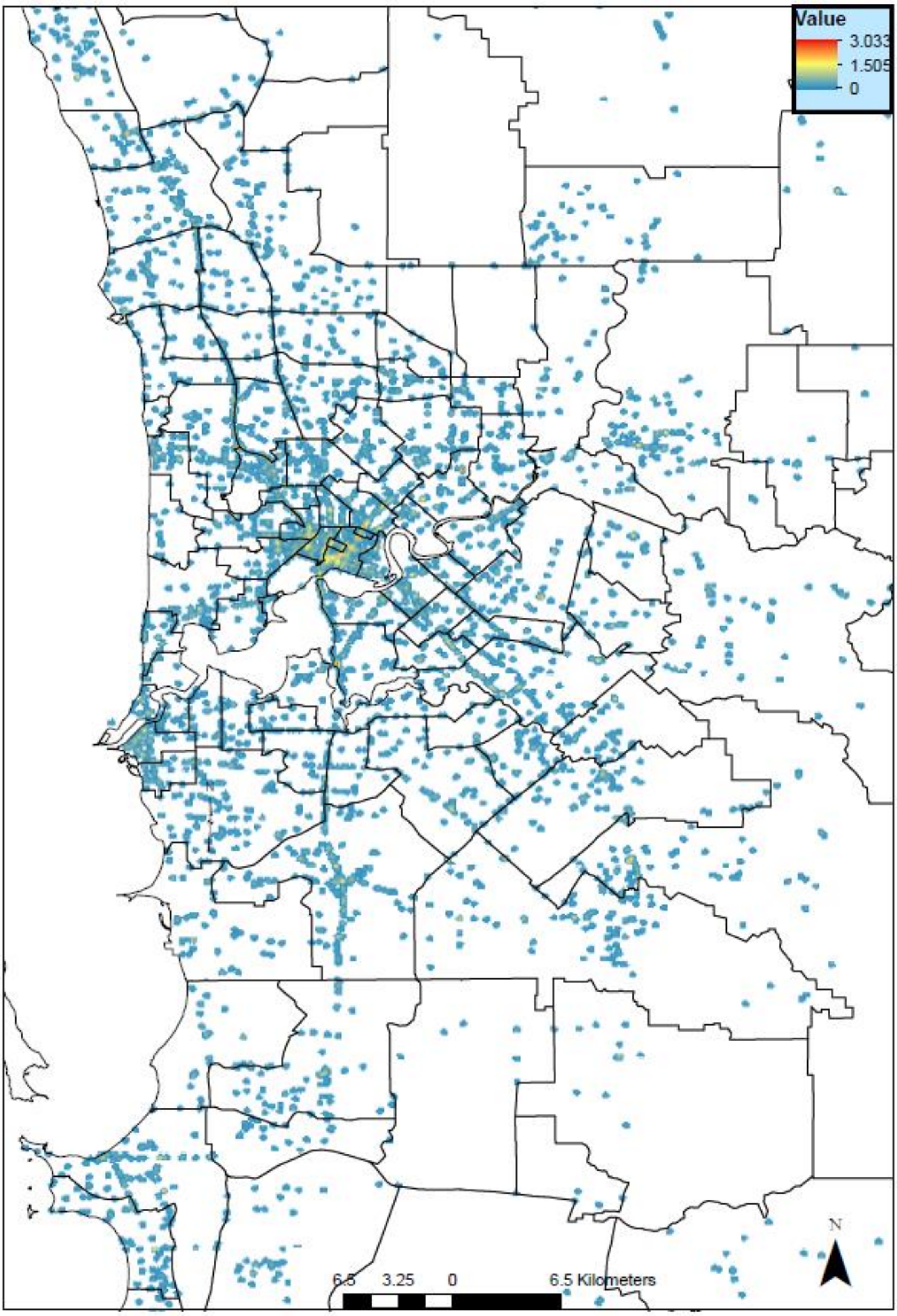


Heat maps indicate the areas with the highest clusters of motorcycle crashes in metropolitan Perth (Maps 3 and 4). The areas with the highest clustering (indicated by red) occurred in the following parts of the metropolitan area:

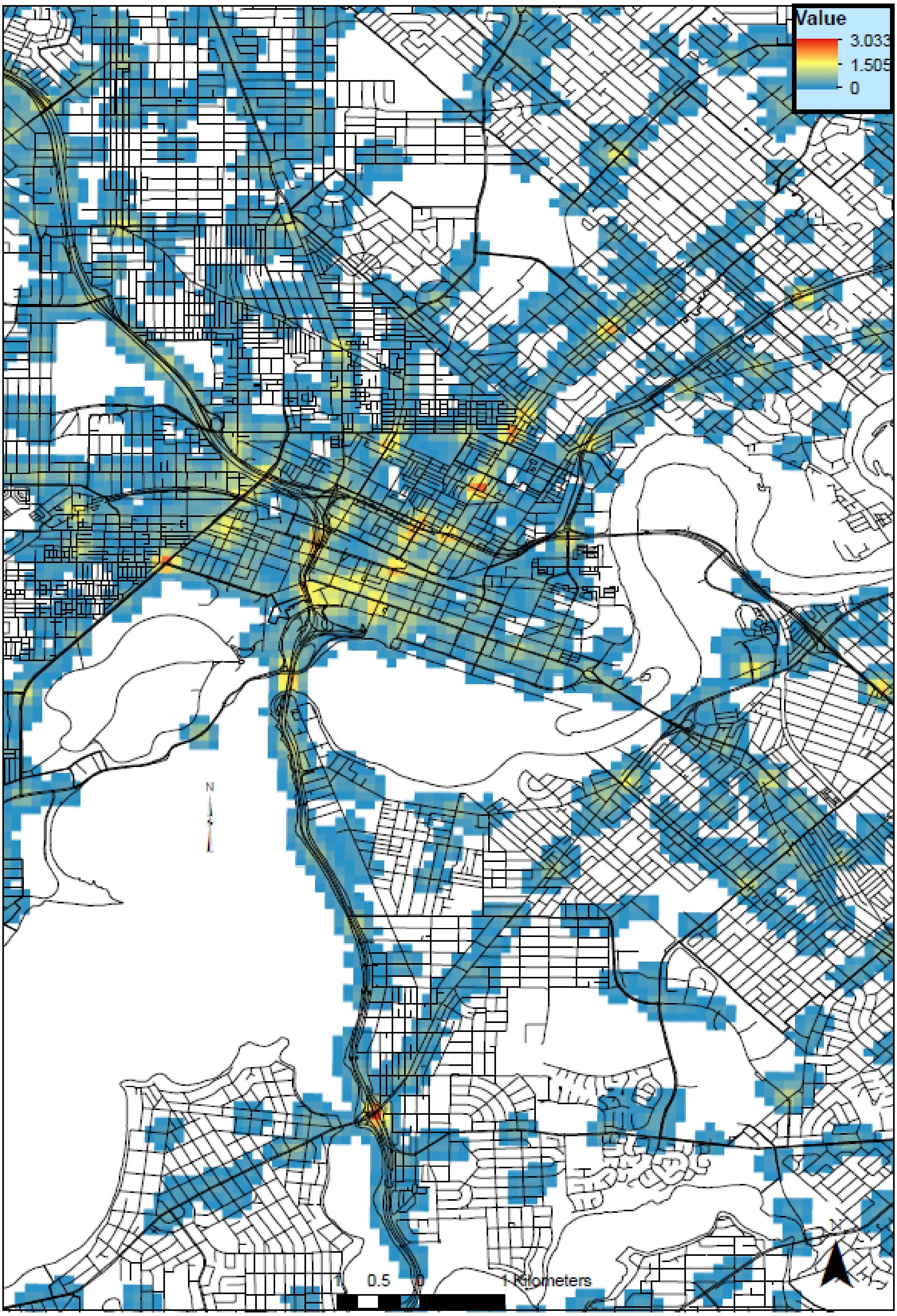
1. The Canning Highway and Kwinana Freeway interchange, Como;
2. Around the intersection of Thomas Street and Kings Park Road, West Perth and Subiaco;
3. Around the intersection of Bulwer Street with McCarthy and Beaufort Streets, Highgate;
4. The Tonkin Highway and Collier Road interchange, Bayswater; and
5. The Tonkin Highway and Horrie Miller Drive/Kewdale Road Interchange, Kewdale and Perth Airport.

As described in the methods section, heat maps were constructed for regional and remote WA. Because of the large geographical area and highly dispersed nature of motorcycle crashes, these heat maps were less helpful in identifying clustering so are not reported here.

Map 3: Heat map of motorcycle crashes between 2013 and 2017, in the Perth metropolitan area



Map 4: Heat map of motorcycle crashes between 2013 and 2017, in central Perth



The intersections with the five or more motorcycle crashes are indicated in Table 12 below. The three intersections with nine of more crashes during the study period are examined in more detail in Section 5.1.

All intersections crashes reported below occurred in the metropolitan area, with the exception of two intersections, which were located in southern WA. Both of these intersections were large double-lane roundabouts and were the location of five crashes each between 2013 and 2017. The first was in Albany (Hanrahan Road, Albany Highway, South Coast Highway and North Road). The second was in Bunbury (Brittain Road, Bussell Highway and Parade Road).

One intersection in WA had two fatal crashes during the study period: the roundabout on Southern River Road, Ranford Road and Ballannup Road. In addition to the two fatal crashes, there were three property damage only crashes at this location. Both fatal crashes occurred in the dark, with street lights on and in the early hours of the morning. The roads has a speed limit of 80km/h. Both crashes were non-collisions (out of control, other) and involved the kerb.

Two additional intersections had a total of five motorcycle crashes, each of which included one fatal crash. The intersection of Armadale Road and Eighth Road, Seville Grove was the site of two hospitalisation crashes and two property damage only crashes. The speed limit is 80km/h. The fatal multi-vehicle crash was a right-angle turn crash at a three-way intersection. This crash was classified as ‘out of control’. It occurred on a straight, level stretch of road, in clear, dry conditions.

The intersection of Winthrop Street, Aberdare Road and Thomas Street, Nedlands was the site of one multi-vehicle fatal crash in addition to four other motorcycle crashes. The fatal crash occurred in clear, dry conditions and in daylight hours, and was at a signalised intersection. Data on the nature of the crash (for example, rear-end crash) was missing but the RUM code indicated that it was on-path following a break-down or crash.

Table 12: Intersections with five or more motorcycle crashes, between 2013 and 2017, in Western Australia

Crash count	Intersection number	Intersection location	Suburb	Postcode	Signalised
11	4541	Tonkin Hwy & Collier Rd	Bayswater	6053	Yes
10	75717	Burns Beach Rd & Connolly Dr	Currambine	6028	No
9	50693	Thomas St & Bagot Rd & Kings Park Rd	West Perth	6005	Yes
8	37900	Whatley Cr & Hotham St Bridge	Bayswater	6053	No
8	52703	Safety Bay Rd & Read St & Warnbro Sound Av	Waikiki	6169	No
8	60418	Whitfords Av & Hepburn Av & West Coast Dr	Sorrento	6020	No
8	36171	Nicholson Rd & Warton Rd	Piara Waters	6112	No
8	50629	Beaufort St & Vincent St	Mount Lawley	6050	No
8	50621	Beaufort St & Bulwer St	Perth City	6000	Yes
7	4543	Tonkin Hwy & Horrie Miller Dr & Kewdale Rd	Kewdale	6105	No
7	60456	Marmion Av & Anchorage Dr & Neerabup Rd	Clarkson	6030	No
7	55048	Karrinyup-Morley Hwy & Wanneroo Rd	Balcatta	6021	Yes
7	4349	Mitchell Fwy Nth Bound & Cedric St & Karrinyup Rd	Innaloo	6018	Yes
7	4317	Ennis Av & Dixon Rd	Rockingham	6168	Yes
6	90889	Mirrabooka Av & Hepburn Av	Landsdale	6065	No
6	52636	Bolton Av & Glenn Pl & Park Rd	Burswood	6100	No
6	55987	Karrinyup-Morley Hwy & West Coast Hwy & Karrinyup Rd & Marmion Av	Karrinyup	6018	Yes
6	75552	Welshpool Rd East & Orrong Rd & Roe Hwy	Welshpool	6106	Yes
6	4547	Tonkin Hwy & Welshpool Rd East	Orange Grove	6109	Yes
6	13837	Ennis Av & Elanora Dr & Grange Dr	Cooloongup	6168	Yes
6	60428	Marmion Av & Hepburn Av	Sorrento	6020	Yes
6	13875	Wanneroo Rd & Joondalup Dr	Neerabup	6031	Yes
6	67708	Loftus St On-Mitchell Hwy East Bound & Loftus St & Leederville Pde	West Perth	6005	Yes
6	4107	Guildford Rd & Guildford Rd & Whatley Cr	Mount Lawley	6050	Yes

Crash count	Intersection number	Intersection location	Suburb	Postcode	Signalised
6	41086	Wilfred Rd & Nicholson Rd & Bannister Rd	Canning Vale	6155	Yes
6	50615	Beaufort St & Newcastle St	Perth City	6000	Yes
5	178523	Ranford Rd & Southern River Rd & Balannup Rd[1]	Harrisdale	6112	No
5	148116	Hanrahan Rd & Albany Hwy & S Coast Hwy & North Rd[2]	Albany	6330	No
5	14855	Great Eastern Hwy & Ferguson St	Midland	6056	No
5	59366	Gnangara Rd & Lord St & Pinaster Pde	Whiteman	6068	No
5	4578	Guildford Rd & Peninsula Rd	Maylands	6051	No
5	65746	Brittain Rd & Bussell Hwy & Parade Rd[2]	Bunbury	6230	No
5	14758	Great Eastern Hwy & Swan St East & Water St	Guildford	6055	No
5	75776	Marmion Av & Shenton Av	Iluka	6028	No
5	45356	Hale Rd & Dawson Av	Forrestfield	6058	No
5	36346	Armadale Rd & Eighth Rd[3]	Seville Grove	6112	No
5	4336	Wanneroo Rd & Newcastle St & Charles St On-Mitchell Hwy Sth & Nth Bound	West Perth	6005	Yes
5	51029	Kent St & Berwick St	East Victoria Park	6101	Yes
5	58619	Winthrop Av & Aberdare Rd & Thomas St[3]	Nedlands	6009	Yes
5	50633	Beaufort St & Walcott St & Beaufort St	Mount Lawley	6050	Yes
5	50561	William St & Wellington St	Perth City	6000	Yes
5	50705	Thomas St & Railway Pde & Loftus St & Railway St	West Perth	6005	Yes
5	4061	Armadale Rd & Nicholson Rd	Piara Waters	6112	Yes
5	13791	Mandurah Rd & Murdoch Dr & Allnutt St East	Greenfields	6210	Yes
5	14306	Albany Hwy & Liege St	Cannington	6107	Yes
5	43023	South St & Carrington St	White Gum Valley	6162	Yes
5	4255	Albany Hwy & Nicholson Rd	Beckenham	6107	Yes

[1] This roundabout in Harrisdale was the location of two fatal motorcycle crashes as well as three other motorcycle crashes.
[2] The intersections in Albany and Bunbury represent the only intersections in regional and remote WA.
[3]The intersections of Armadale road and Eighth Road, Seville Grove and Winthrop Avenue, Aberdare Road and Thomas Street, West Perth each were the location of one fatal and four additional motorcycle crashes.

Map 5 and Table 13 show the road sections, as defined by the IRIS unique identifier, where there were eight or more motorcycle crashes in the study period (2013 to 2017). All but one reported road sections are in the metropolitan area. The exception was a section of the Chester Pass Rotary in Albany, which had nine crashes during the study period.

The road section with the most motorcycle crashes was on the Kwinana Freeway, between the off-ramp to Armadale and the on-ramp to Russell Road (adjacent to the suburbs of Success and Atwell). There were 20 crashes along this section of road during the study period. Of the 32 road sections with eight or more crashes during the study period, 17 sections were on either the Kwinana or Mitchell Freeways.

There were two fatal crashes each on two road sections in WA between 2013 and 2017. One road section is located on Julimar Road in Chittering, in the Wheatbelt. It was the site of six motorcycle crashes (two hospital crashes and two property damage only crashes as well as two fatal crashes). Both crashes occurred on a Saturday afternoon on a curve and a slope, in dry conditions. The other four crashes at this location occurred in similar conditions. The speed limits was 90km/h to 110km/h along this stretch of road. One fatal crash was a hit object, a drainage ditch (RUM code: off right bend into object) and the other was a head-one crash (RUM code: right thru). The colliding vehicle was out of control in both cases.

The second road section includes the roundabout on Southern River road and is discussed above as the fatal crashes occurred at this intersection.

Map 5: Location of road sections with eight or more motorcycle crashes between 2013 and 2017, in the Perth metropolitan area (highlighted in red)

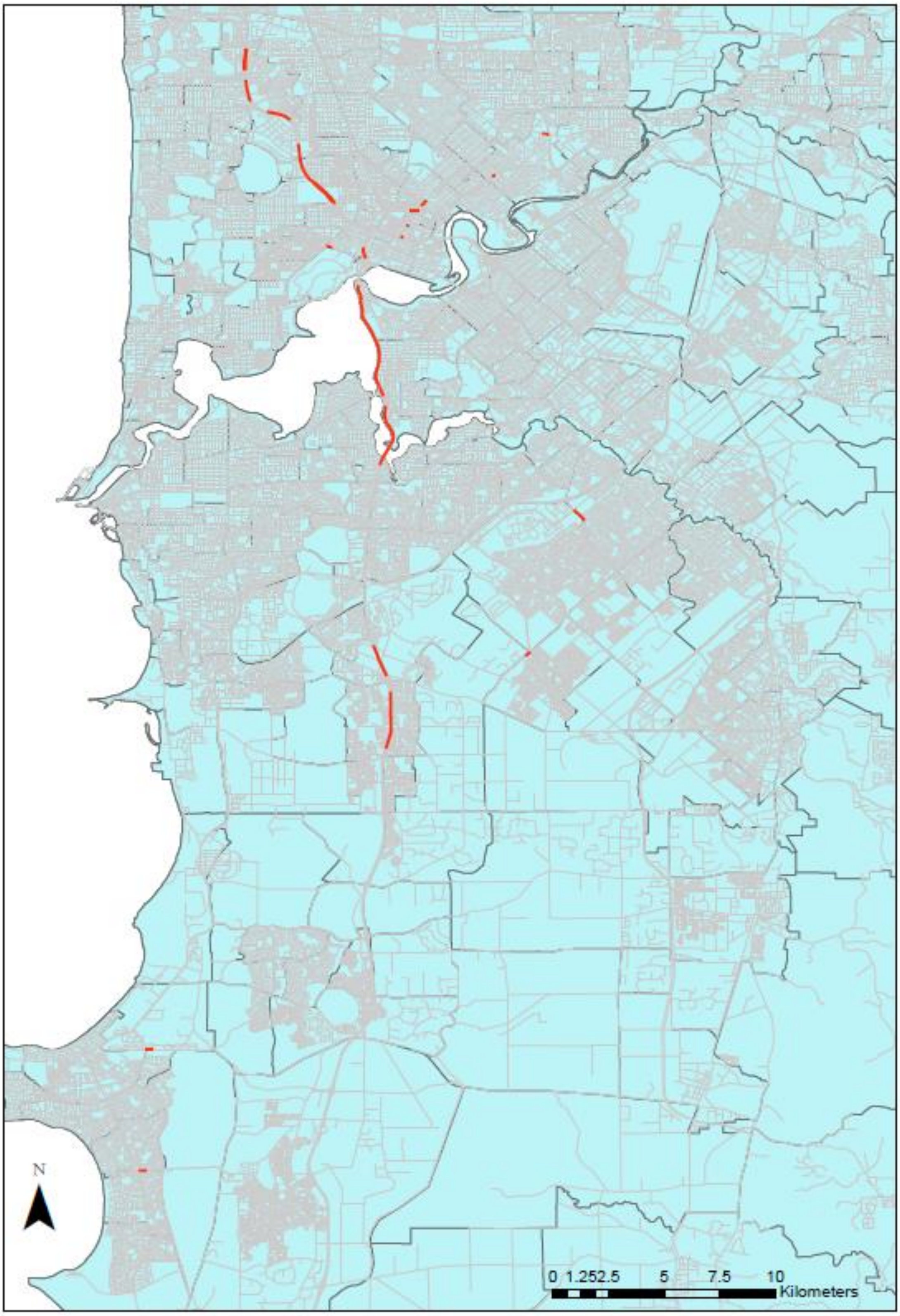


Table 13: Road sections with eight or more motorcycle crashes, between 2013 and 2017, in Western Australia

Crash count	Road name	Suburb	From	To
20	Kwinana Fwy	Success/Atwell	Kwinana Fwy (Northbound) off to Armadale Rd	Russell Rd on to Kwinana Fwy (Northbound)
16	Kwinana Fwy	South Perth/Como	Mill Point Rd on to Kwinana Fwy (Northbound)	Canning Hwy (Eastbound) on to Kwinana Fwy (Northbound)
13	Nicholson Rd	Canning Vale/Thornlie	Wilfred Rd & Bannister Rd & Nicholson Rd	Yale Rd & Garden St
12	Kwinana Fwy	Cockburn Central/Jandakot	Kwinana Fwy (Northbound) off to Berrigan Dr	Armadale Rd on to Kwinana Fwy (Northbound)
11	Collier Rd[1]	Bayswater	Tonkin Hwy	Spencer St
11	Mitchell Fwy	Leederville	Mitchell Fwy (Southbound) off to Vincent St	Powis St on to Mitchell Fwy (Southbound)
10	Dixon Rd	Rockingham	Ennis Av	Nasmyth Rd
10	Kings Park Rd	West Perth	Bagot Rd & Thomas St	Walker Av
10	Burns Beach Rd	Currambine/Kinross	Connolly Dr	Marmion Av
10	Kwinana Fwy	Como	Canning Hwy on to Kwinana Fwy (Northbound)	Manning Rd on to Kwinana Fwy (Northbound)
10	Mitchell Fwy	Perth City	Mitchell Fwy (Southbound) off to Riverside Dr	Murray St on to Mitchell Fwy (Southbound)
10	Mitchell Fwy	Inaloo/Stirling	Karrinyup Rd on to Mitchell Fwy (Southbound)	Mitchell Fwy (Southbound) off to Cedric St
9	Beaufort St	Mount Lawley	Beaufort St & Walcott St	Queens Cr
9	Chester Pass Rty	Albany	North Rd	Albany Hwy
9	Kwinana Fwy	South Perth	Narrows Bridge	Kwinana Fwy (Southbound) off to Mill Point Rd
9	Mitchell Fwy	Leederville	Vincent St on to Mitchell Fwy (Northbound)	Mitchell Fwy (Northbound) off to Powis St
9	Mitchell Fwy	Gwelup/Stirling	Mitchell Fwy (Southbound) off to Karrinyup Rd	Erindale Rd on to Mitchell Fwy (Southbound)
9	Mitchell Fwy	Craigie/Woodvale	Mitchell Fwy (Southbound) off to Whitfords Av	Ocean Reef Rd on to Mitchell Fwy (Southbound)
8	Warton Rd	Canning Vale/Piara Waters	Erade Dr	Warton Rd & Nicholson Rd
8	Beaufort St	Perth City	Newcastle St & Beaufort St	Little Parry St & Parry St
8	Safety Bay Rd	Warnbro	Warnbro Sound Av & Read St	Ambleside Pde
8	Bulwer St	Highgate	Beaufort St	Grant St
8	Old Yanchep Rd	Yanchep	Cutler Rd	Indian Ocean Dr

[1] Note that all crashes on this stretch of road were intersection crashes, occurring at the Tonkin Highway and Collier Road intersection so this road section will not be discussed further.

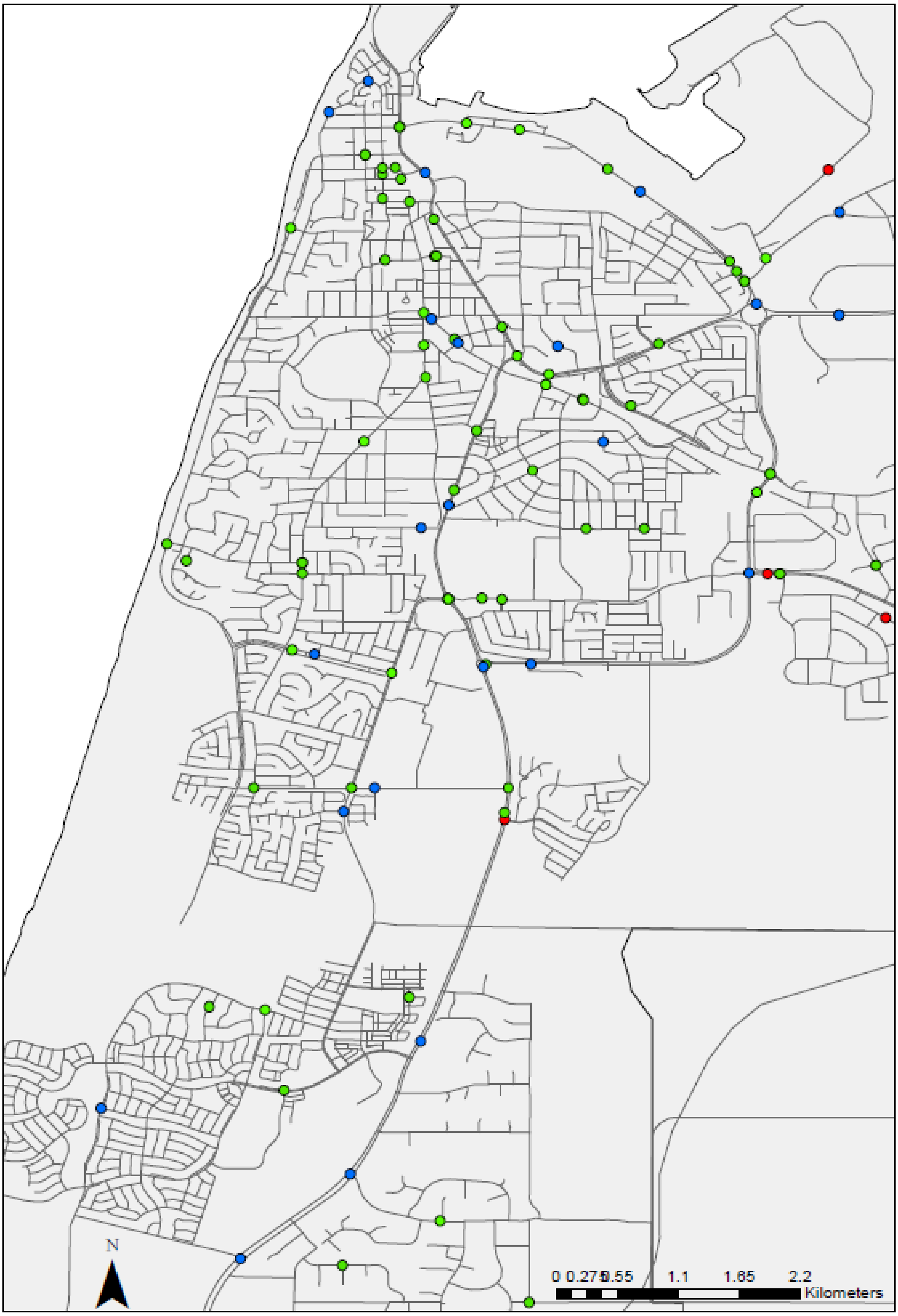
Crash count	Road name	Suburb	From	To
8	Vincent St	Highgate/Mount Lawley	Harold St	Beaufort St
8	Whatley Cr	Bayswater	Hotham St Bridge	Grafton Rd
8	West Coast Dr	Sorrento	St Helier Dr	Whitfords Av & Hepburn Av
8	Kwinana Fwy	Salter Point	Kwinana Fwy (Northbound) off to Canning Hwy	-
8	Kwinana Fwy	Brentwood	-	Cranford Av on to Kwinana Fwy (Northbound)
8	Mitchell Fwy	Glendalough	Mitchell Fwy (Northbound) off to Powis St	-
8	Mitchell Fwy	Osborne Park	-	Mitchell Fwy (Northbound) off to Hutton St
8	Mitchell Fwy	Gwelup	Karrinyup Rd on to Mitchell Fwy (Northbound)	Mitchell Fwy (Northbound) off to Erindale Rd
8	Mitchell Fwy	Osborne Park/Stirling	Mitchell Fwy (Southbound) off to Hutton St	Cedric St on to Mitchell Fwy (Southbound)

Maps 6 to 10 display the location of motorcycle crashes in the five high-risk regional and remote towns in WA. On each map, a red symbol indicates a fatal motorcycle crash, a blue symbol indicated a motorcycle crash leading to hospitalisation and a green symbol indicates all other motorcycle crashes (requiring medical treatment or property damage only).

Map 6 shows the location of motorcycle crashes between 2013 and 2017 in Bunbury (postcode 6230, 115 crashes). Crashes were scattered throughout the town, with several crashes occurring along the major roads with speed limits above 50km/h (Koombana Drive, Blair Street Sandridge Road and parts of Brittain Road). A cluster of crashes occur in the CBD, containing the shopping area and many restaurants (to the west of Blair Street). Most of this area has a speed limit of 50km/h.

There were four fatal crashes indicated in the map and one additional fatal crash beyond the map boundaries. Two were intersection crashes (at different three-way intersections). The crashes included two right-angle crashes, a non-collision, a sideswipe (while overtaking) and a hit object (a tree and scrub); three multi-vehicle and two single-vehicle crashes. The crashes occurred throughout the week during daytime hours.

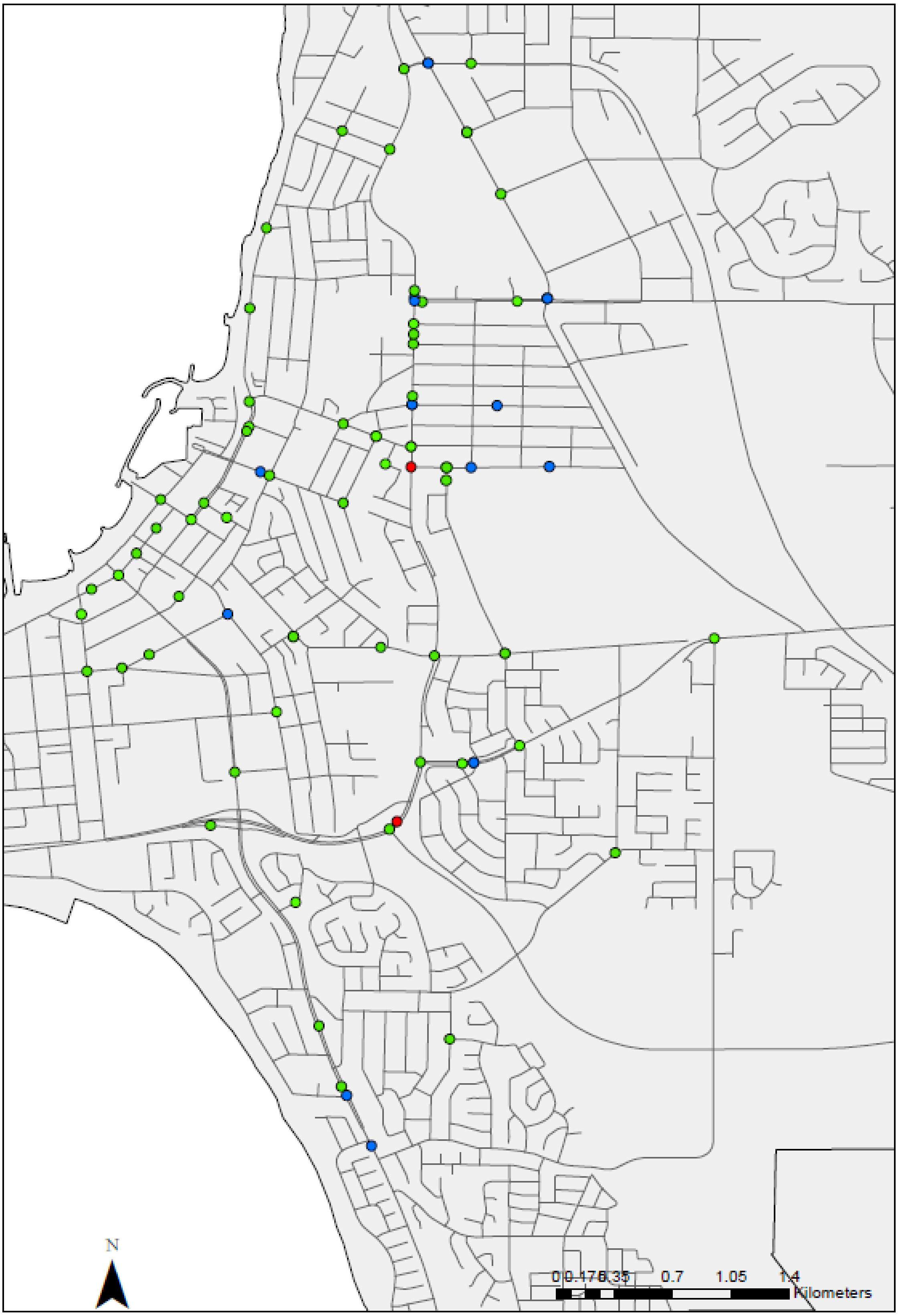
Map 6: Location of motorcycle crashes between 2013 and 2017, in Bunbury (postcode 6230) - fatal crashes in red, hospitalisation crashes in blue and other crashes in green.



Map 7 shows the location of motorcycle crashes between 2013 and 2017 in Geraldton (postcodes 6530, 92 crashes). The crashes in Geraldton tended to be located along the higher speed roads (60km/h and 70km/h). These include a section of Chapman Road (between Cathedral Road and Phelps Street), Brand Highway as it skirts the CBD, and the North West Coastal Highway (adjacent to Wonthella). A section of Marine Terrace (between Fitzgerald Street and Cathedral Avenue; speed limit 50km/h) had several crashes. There was also a cluster of crashes near the shopping district close to St Francis Xavier Cathedral.

There were two fatal motorcycle crashes during the study period, one at a three-way intersection in rainy weather (a right thru turn), and the other was a midblock crash (sideswipe same direction). Both were night-time crashes, with streetlights on and were multi-vehicle crashes.

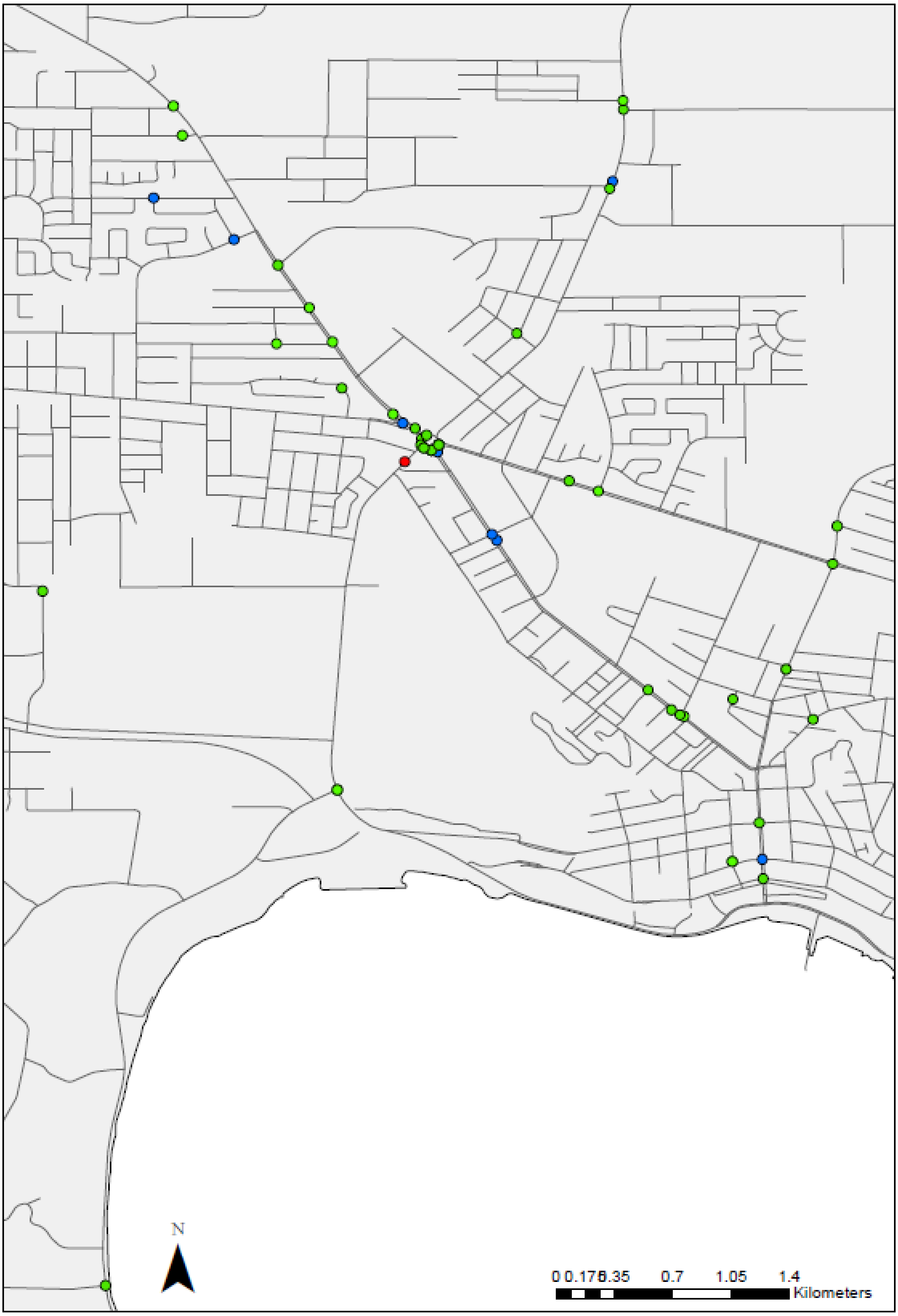
Map 7: Location of motorcycle crashes between 2013 and 2017, in Geraldton (postcode 6530) – fatal crashes in red, hospitalisation crashes in blue and other crashes in green.



Map 8 shows the location of motorcycle crashes between 2013 and 2017 in Albany (postcodes 6330, 85 crashes). As described earlier, five motorcycle crashes occurred at the (five leg) roundabout where South Coast Highway (traffic volume: 6,118), Chester Pass Road (traffic volume: 11,791), Albany Highway (traffic volume: 13,346), North Road (traffic volume: 16,029) and Hanrahan Road (traffic volume: 9,256) converge. (All traffic volumes are daily averages between Monday and Sunday, measured in 2017/18.) Notably, there were several more motorcycle crashes close to the roundabout, and several more within 2.5km of Albany Road on either side of the roundabout. Chester Pass Road north-west of the roundabout is also the site of several motorcycle crashes over the study period. All roads leading into the roundabout had speed limits of 60km/h. Several other crashes occurred in the CBD of Albany, including Ulster Road (which has speed limits of 60km/h) and its continuation, Lockyer Ave (speed limit 50km/h).

There were three fatal crashes in the Albany area: one close to town and two outside town. All three were midblock crashes occurring in dry weather. The crashes included a right-angle crash, a head-on crash and one hit object (a guide post and a tree).

Map 8: Location of motorcycle crashes between 2013 and 2017, in Albany (postcode 6330) – fatal crashes in red, hospitalisation crashes in blue and other crashes in green.

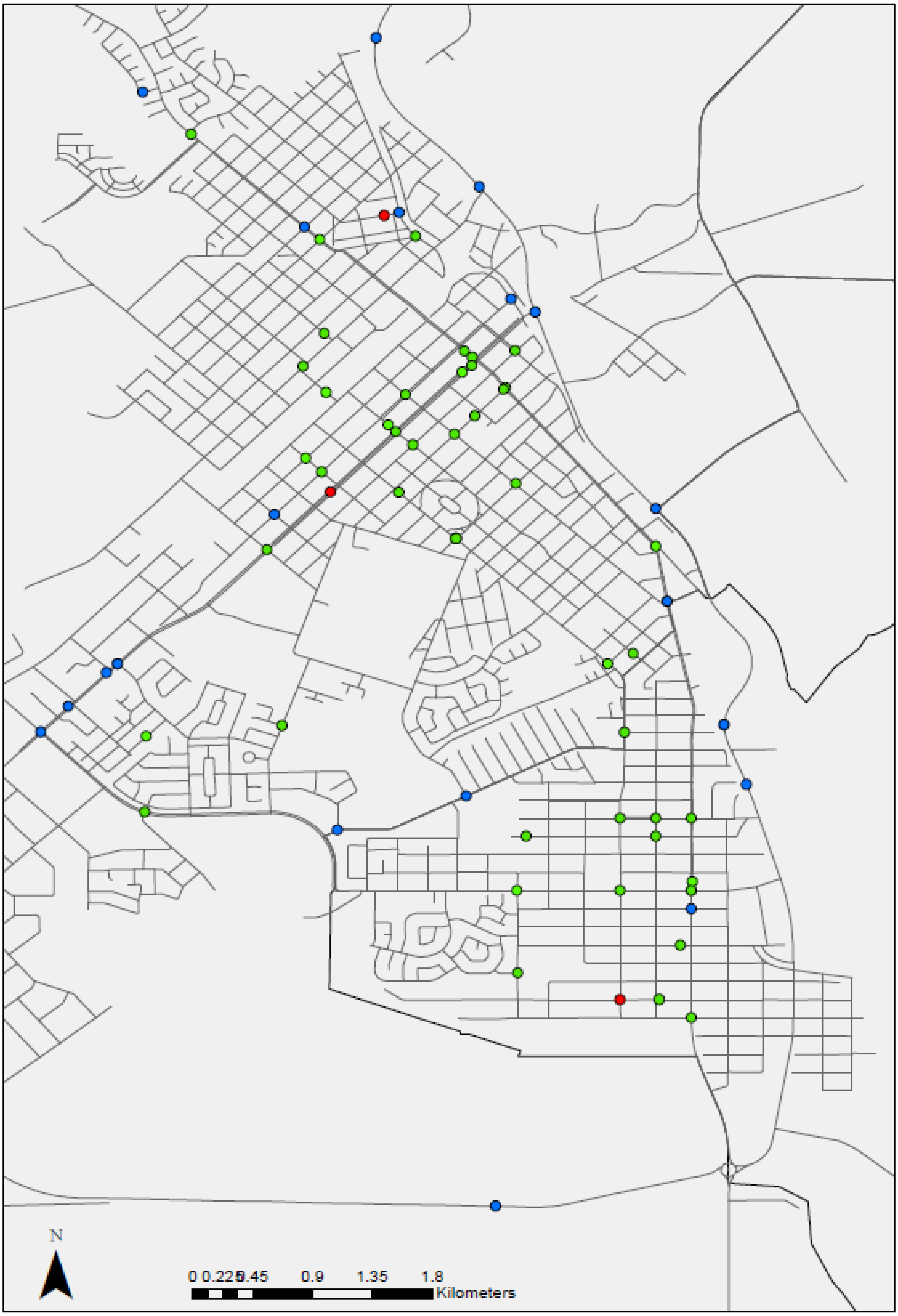


Map 9 shows the location of motorcycle crashes between 2013 and 2017 in Kalgoorlie (postcodes 6430, 59 crashes and 6432, 20 crashes). A high number of crashes occurred along the stretch of road including Hannon Street (and its crossroads) and Great Eastern Highway, between Gatacre Drive and Wingate Street. Hannon Street was traversed by an average of 8,273 vehicles per day in 2013/14, and Great Eastern Highway (near Gatacre Drive) by 8,087 vehicle per day in 2017/18, Monday to Sunday. The latter road had a speed limit of 110km/h.

In Boulder, crashes occurred along the three parallel roads: Lionel Street, Brockman Street and Lane Street (all of which have speed limits of 60km/h). Boulder Road (60km/h) was also the site of several motorcycle crashes.

There were three fatal crashes in Kalgoorlie – two in postcode 6530 and one in 6532. One, at an intersection, was a right turn thru. The other two were a sideswipe and a hit object (power pole and drainage ditch). One crash occurred at dusk and the other two at night.

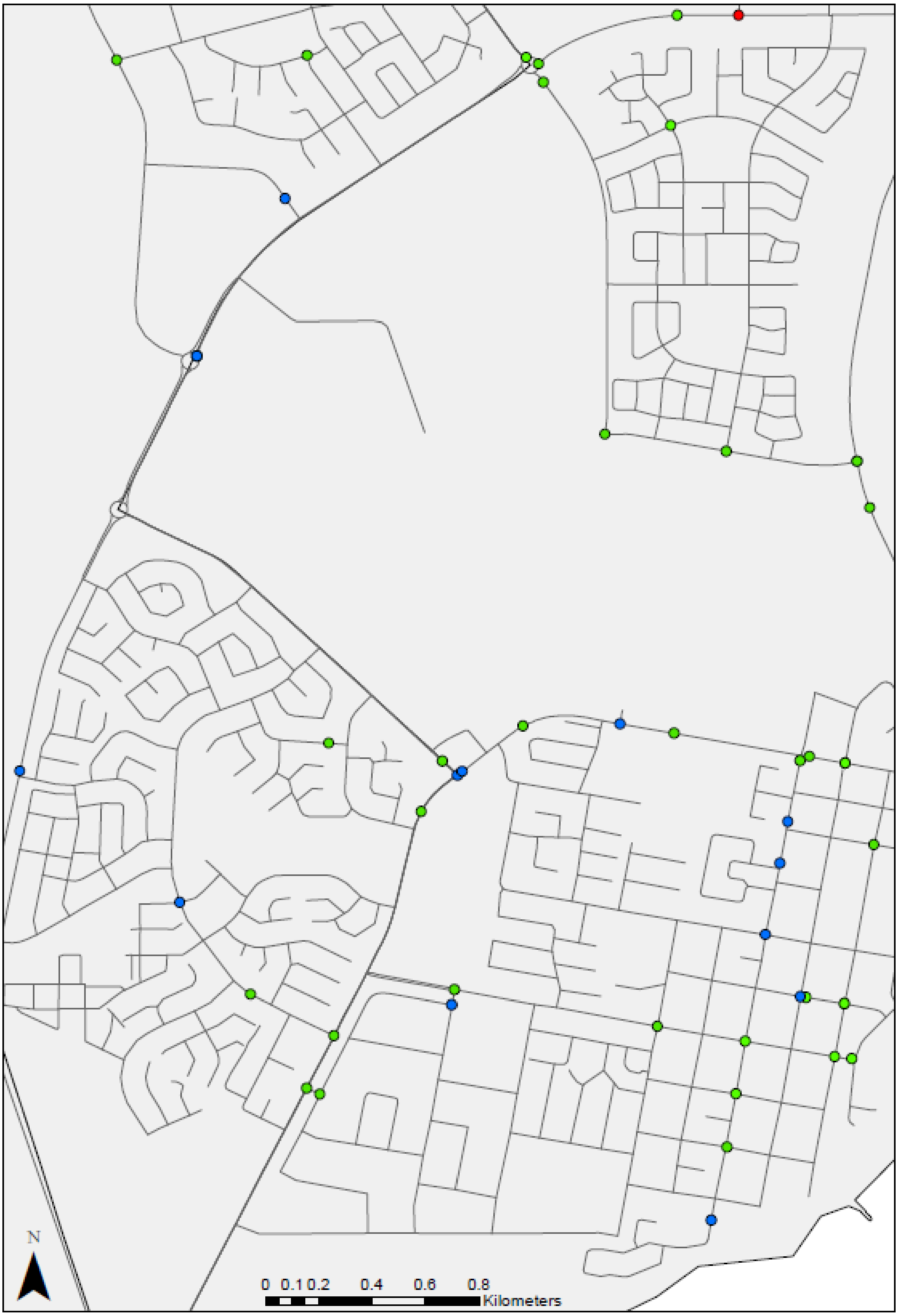
Map 9: Location of motorcycle crashes between 2013 and 2017, in Kalgoorlie (postcodes 6430 and 6432) – fatal crashes in red, hospitalisation crashes in blue and other crashes in green.



Map 10 shows the location of motorcycle crashes between 2013 and 2017 in Broome (postcodes 6725, 60 crashes and 6726, 10 crashes). Crashes appear to be scattered throughout. Many crashes are located in the area south of the airport, primarily at the intersections along Herbert Street (which has a speed limit of 50km/h). Other roads with higher numbers of crashes include Frederick Street (60km/h) and Carnarvon Street (50km/h), where many restaurants and bars are located. A cluster of crashes occurred near the Jigal Drive Rotary (Jigal Drive, Gubinge Road and Fairway Drive) where a 50km/h road connects with a 60 to 70km/h road.

There was a single fatal crash in Broome. It occurred at a three-way intersection in clear conditions at night (lights on). It was a non-collision involving a kerb.

Map 10: Location of motorcycle crashes between 2013 and 2017, in Broome (postcodes 6725 and 6726) – fatal crashes in red, hospitalisation crashes in yellow and other crashes in black.



5 ANALYSIS AND COUNTERMEASURES APPROPRIATE TO HIGH RISK MOTORCYCLE AREAS

Areas with clusters of motorcycles are examined in more detail below. This included the three intersections with nine or more crashes between 2013 and 2017, the six road sections with eleven or more crashes during the study period, and the five regional areas with the highest number of crashes per postcode.

5.1 High risk intersections

5.1.1 Tonkin Highway and Collier Road, Bayswater (intersection number 4541)

This intersection, located in the Perth metropolitan areas, was the site of 11 motorcycle crashes during the study period. Tonkin Highway has a speed of 100km/h while Collier Road has a speed of 60 to 70km/h adjacent to the intersection[11]. This was a signalised four-way intersection [Figure 6(i)] which was converted into an unsignalised (grade-separated) interchange [Figure 6(i)] with multiple on- and off-ramps (eight in total) toward the end of 2017 (that is, at the end of the study period). Notably, four of the crashes occurred in 2014 and four were in 2015, prior to this change.

All but one crash were property damage only crashes; this crash resulted in injuries requiring medical treatment but not hospitalisation. Four of the crashes occurred in March and four occurred on a Friday. Nine crashes occurred on weekdays, with the other two occurring on a Saturday. The crashes occurred throughout the day, although four occurred between 8am and 9:59am, suggesting times of high traffic volumes. All crashes occurred in dry conditions. Seven of the crashes were rear-end crashes (six while stopped at the traffic lights and the other involving a loss of control). The remaining three were sideswipes (in the same direction; two of involved overtaking).

The new interchange is larger than the previous four-way intersection and may provide improved visibility of motorcycles through improved sight distance and clear sight lines (Steinmetz and Aumann, 2017), reducing the risk of rear-end crashes. Further analysis of crash data following the installation of the interchange (from 2018 onwards) will demonstrate whether there has been a reduction in motorcycle crashes following this change.

[11] Speed limits were sourced from Main Roads Western Australia’s Road Information Mapping System.
MAIN ROADS WESTERN AUSTRALIA 2019a. Road Information Mapping System. Perth, Western Australia: Main Roads Western Australia..

Figure 10: Tonkin Highway and Collier Road intersection, Bayswater i) before and ii) after conversion to an interchange

i)

ii)

5.1.2 Burns Beach Road and Connolly Drive, Currambine (intersection number 75717)

This intersection, also located in the Perth metropolitan area, was the location of 10 motorcycle crashes over the study period. It is a double-lane roundabout (Figure 7). Both Burns Beach Road and Connolly Drive have speed limits of 70km/h[11].

There were two crashes in each of the five years of the study, except for 2013 (one crash) and 2015 (three crashes). Seven crashes were property damage only, two resulted in hospitalisation and one in medical treatment only. Three crashes were on a Thursday. Five crashes occurred between 16h00 and 18h00, when traffic volumes were likely to be higher. Four crashes were rear-end crashes, and three were right-angle crashes (exiting the roundabout). The remaining three crashes were non-collisions (that is, single-vehicle crashes). One of these was a result of loss of control while swerving to avoid a vehicle, and the second involved a loss of control because of a domestic animal. The third was the result of loss of control because of road conditions; however, there were no details on the road conditions recorded in the IRIS other than that the road was sealed. It is unknown whether inappropriately high speeds contributed to these crashes.

Roundabouts are designed to reduce speeds of approaching vehicles, particularly motor cars and trucks. However, this may be less effective with motorcycles as they are smaller and more agile. A series of poles at a height which can block or reduce line of sight for a motorcyclist only, not other motorised vehicles, may force motorcyclists to slow down further at the entry point of the roundabout and reduce their speeds through the roundabout by reducing sight distance, thus reducing conflicts with other vehicles and loss-of-control crashes. Future roundabout designs should also consider that the entry angle. If it is too high, it can lead to high speeds on approach while an entry angle that is too low can block the motorcyclists from other drivers' sight (Delhaye and Marot, 2015). Warning signs to other motor vehicles and improved street lighting could also be used at this roundabout to alert motor vehicles of the presence of and risk to motorcyclists in the roundabout (Steinmetz and Aumann, 2017).

Figure 11: Burns Beach Road and Connolly Drive, Currambine

5.1.3 Thomas Street/Bagot Road and Kings Park Road, West Perth (intersection number 50693)

This intersection, where nine motorcycle crashes occurred, is located close to the Perth Central Business District (CBD). This is a signalised, four-way intersection (Figure 8) and Thomas Street, Bagot Road and Kings Park Road have speed limits of 60km/h. Each approach road contains multiple lanes, and there are medians separating the northern/southern, and eastern/western carriageways for each.

Seven of the nine crashes at this intersection involved property damage only, with one crash resulting in a hospitalisation and the other crash resulting injuries requiring medical treatment. Four crashes were in March and all occurred during the weekdays. Seven of the crashes occurred between 15h00 and 16h30. Eight crashes were rear-end crashes, of which seven were same lane rear-end crashes and one was a same lane left rear-end crash. Three of the rear-end crashes involved overtaking. These crashes suggest poor visibility contributed to the crashes. There was only one single vehicle (non-collision, out-of-control) crash.

This pattern of crashes suggests that, in addition to motorcycle-specific measures to improve visibility (see Section 5.2.7), treatments could be used at this intersection to improve visibility and reduce crash risk. A motorcycle lane could be provided specifically at the intersection, or lanes could be widened to allow motorcycles to filter to the front of the queue. Warning signage, pavements markings or vehicle-activated signs could also be used to alert drivers to the intersection ahead and the presence of motorcycles (Steinmetz and Aumann, 2017).

Figure 12: Thomas Street/Bagot Road and Kings Park Road, West Perth

5.2 High risk road sections

Three of the five road sections with the highest number of crashes over the study period were located on the Kwinana or Mitchell Freeways. Possible countermeasures to improve motorcycle safety at high risk road sections are discussed below in Section 5.2.7.

5.2.1 Kwinana Freeway, Success/Atwell

This stretch of the Kwinana Freeway had the highest number of motorcycle crashes of all road sections in WA over the study period (20 crashes). It has a speed limit of 100km/h. Travelling northbound from the Armadale Road on-ramp, the road is straight until it curves slightly eastwards and straightens as it approaches the Russell Road off-ramp. This section of freeway consists of a northbound and southbound carriageway, separated by the rail tracks which are part of the Mandurah Line. It had a mean traffic volume of 47,121 (southbound) and 55,643 (northbound) per day between Monday to Friday in 2017/18 (Main Roads Western Australia, 2019b).

Visual inspection of the NearMap time series showed that each carriageway had two lanes at the start of the study period. In the second half of 2016, an additional lane was added to the southbound carriageway. A third northbound lane was being constructed in first half of 2019. This section of road is highly congested throughout the daytime hours, encouraging ‘lane filtering’ (moving between two or more lanes of traffic at speeds of 30km/h or less, a practice that became legal in WA in 2018).

Fourteen of the crashes resulted in property damage only, three required medical treatment, and three required hospitalisation. Thirteen of the twenty crashes occurred between 6am and 7:59am, and eleven crashes were in 2016 or 2017. Thirteen crashes were sideswipes (same direction) and three were rear-end crashes. Two involved hitting an object, both because the motorcycle was out of control, and were classified as run-off road crashes. One of these crashes resulted from hitting the guard rail. Both of these crashes resulted in hospitalisation. The remaining two were non-collisions (single-vehicle crashes): overturns following a loss of control.

5.2.2 Kwinana Freeway, South Perth/Como

This section of the Kwinana freeway had the second highest number of motorcycle crashes of all road sections in WA (16 crashes). It has a speed limit of 100km/h that changes to 80km/h closer to the CBD. A high volume of traffic travels along this stretch of Kwinana Freeway during peak traffic hours. However, traffic volumes are only available for the Mill Point Road and Canning Highway on- and off-ramps (Main Roads Western Australia, 2019b). This section of freeway consists of a northbound and southbound carriageway, separated by the rail tracks in both directions. Each carriageway has three lanes. Visual inspection of the NearMap time series (Nearmap Ltd., 2016) found no major structural changes since the start of the study period (2013).

Eleven crashes resulted in property damage only, four required hospitalisation and one required medical treatment. Eleven crashes occurred between 6am and 8:59am, representing the morning peak traffic. All but one crash occurred on a dry road. A quarter of the crashes along this road occurred in March. Seven crashes were rear-end crashes and five were sideswipes (same direction). Of these 12 crashes, five occurred during overtaking. Four crashes were non-collisions, all involving loss of control and overturning.

5.2.3 Nicholson Road, Canning Vale/Thornlie

This road section (not on a freeway) has a speed limit of 60km/h and was the site of 13 motorcycle crashes during the study period. An average of 53,957 vehicles per day travelled on this stretch of road between Mondays and Fridays in 2016/17 (Main Roads Western Australia, 2019b).

Eight of the crashes involved property damage only, four led to hospitalisation and one was a medical treatment only crash. All but two crashes occurred during weekdays. Eight of the thirteen crashes occurred between 4pm and 6:59pm.

Ten crashes occurred at an intersection. The road section covers two intersections: i) the four-way intersection of Nicholson Road with Bannister Road and Wilfred Road (six of the intersection crashes) and ii) the roundabout with the approach roads Nicholson Road, Garden Street and Yale Road (four crashes).

The four-way intersection, the site of six of the thirteen crashes, is a signalised intersection, consisting of two lanes in each direction in Bannister Road, a single lane in each direction in Wilfred Road and three lanes in each direction on Nicholson Road. In addition, all four legs of the intersection have separate turning lanes, with signalised pedestrian crossings and split medians, making it a complex environment for motorcyclists. Of the six crashes occurring at the four-way intersection, four were rear-end crashes, with one sideswipe (same direction). Half of these six crashes involved overtaking. The final crash was non-collision (single-vehicle crash) involved a loss of control and overturn.

The roundabout was the site of four crashes. It is a double-lane roundabout. All entry and exit legs are double lane (four entry and four exit lanes in total). In addition, the turning lanes from Nicholson Road into Yale Road, and as Nicholson Road turns 90 degrees, circumvent the roundabout. Given the relatively high approach speeds (60km/h) and complex nature of the intersection, it is potentially challenging for vulnerable road users such as motorcyclists and bicyclists. It was the site of two non-collisions, a sideswipe (same direction) and one hit object crash. The latter involved a hitting a kerb when swerving to avoid a vehicle. Two crashes occurred in wet conditions (both non-collisions, involving a loss of control). One crash, which occurred in unknown road conditions, involved overtaking (cutting in from the left).

Of the three midblock crashes, one was a rear-end crash and the other two were non-collisions.

5.2.4 Kwinana Freeway, Cockburn Central/Jandakot

This stretch of the Kwinana freeway was the site of 12 motorcycle crashes between 2013 and 2017. It has a speed limit of 100km/h. Average traffic volumes per day (2014/15) were 59,197 northbound, and 62,065 southbound between Monday and Friday (Main Roads Western Australia, 2019b).

At the start of the study period, both northbound and southbound carriageways had two lanes each. During 2015 and 2016, a third lane was added to the southbound carriageway (Nearmap Ltd., 2016). The most recent Nearmap map indicates that a third northbound being constructed as of early 2019.

Seven of the crashes were property only, two involved hospitalisation and the remaining three required medical treatment. Eleven of the twelve crashes occurred on weekdays. Ten of the crashes occurred between 6am and 8am or between 5pm and 5:59pm. All but one crash was a sideswipe (same direction), while overtaking. Two were on a curve with the remaining crashes occurring on the straight

5.2.5 Collier Road, Bayswater

All crashes on this stretch of road occurred at an intersection and are described in Section 5.1.1 above.

5.2.6 Mitchell Freeway, Leederville

This section of the Mitchell Freeway was the site of 11 motorcycle crashes. It located relatively close to the CBD, but has a speed limit of 100km/h, which transitions to 80km/h just south of this section of road (Main Roads Western Australia, 2019a). The closest available traffic volumes were at the Vincent Street Bridge end of the Mitchell Freeway: 89,251 vehicles per day northbound and 71,933 vehicles per day southbound (Monday to Friday, 2015/16) (Main Roads Western Australia, 2019b).

This busy stretch of road has multiple lanes – up to five main lanes northbound and four southbound with additional lanes leading to and from on- and off-ramps respectively (Nearmap Ltd., 2016). These multiple, changing lanes require merging into the traffic by all vehicles. Given the small size (and resulting lower visibility) of motorcycles, they are highly vulnerable in these conditions, especially given the high traffic volumes along this stretch of road.

Five crashes occurred between 7am and 8:59am, with a further four occurring between 4pm and 5:59pm, suggesting an increased risk of crash during peak hours, when the road section is at the highest congestion levels.

Ten of the crashes were property damage only, with one crash requiring medical treatment only. All the crashes occurred during the week, with four taking place on a Thursday. All crashes occurred between February and August. Five crashes were sideswipes (same direction) and four were rear-end crashes. Five of these nine crashes involved overtaking. Two were non-collisions (single-vehicle crashes) involving overturns following loss of control.

5.2.7 Countermeasures to improve motorcycle safety on high risk road sections

Four of the five high risk road sections discussed above were part of freeways (with speed limits of 80 to 100km/h and no traffic signals). Along these sections of roads, most crashes were sideswipes or rear-end crashes, often involving overtaking, with fewer non-collision crashes.

The high proportion of side swipes and rear-end crashes suggests that poor visibility of motorcycles and their motorcyclists may be affecting their crash risk. Recommendations regarding this encompass both the *'safe road users'* and *'safe roads'* pillars of the Safe System Approach (Office of Road Safety, 2009). Encouraging the wearing of high visibility, protective clothing (helmets, jackets, gloves and footwear) would improve the conspicuity of motorcyclists (Wells et al., 2004) and reduce injury severity in the event of a crash (de Rome et al., 2014, Brown et al., 2015). Mandating the daytime running lights (DRL) – which cannot be turned off – on all new motorcycles and the use of parking headlights of older motorcycles has been shown to improve visibility, reducing motorcycle crash risk by 4% to 20% (Davoodi and Hossayni, 2015).

Regarding the *'safe roads'* pillar, roads tend to be designed with motor cars' needs in mind, rather than those of motorcycles (Delhaye and Marot, 2015). As the only major vulnerable road user group who are legally permitted to use freeways, they are particularly vulnerable to the high speeds on these roads. The type of barriers or guard rails used and their effect on the motorcyclists involved in crashes has been the subject of concern by researchers and motorcycle advocacy groups (EuroRAP, 2008, Grzebieta et al., 2013). However, only one crash in the high-risk intersections and road sections was reported to involve a guard rail. As discussed earlier, treatments can be added to guard rails to protect motorcyclists from more severe injuries when crashes occur (Anderson et al., 2012, Milling et al., 2016).

Exclusive motorcycle lanes, separated from the general traffic with a physical barrier or structure, are used in Asian countries with high volumes of motorcycle traffic (WHO, 2017). This has been shown to be helpful on higher speed roads, to reduce crashes and reduce congestion. Research in Malaysia has found that motorcycle lanes reduce motorcycle crashes and are beneficial when the proportion of motorcycle users is 20% to 30% of all vehicles (Radin Sohadi et al., 2000, WHO, 2017). This option needs further investigation given the different traffic mix in WA but could be considered on high motorcycle volume parts of the Kwinana Freeway.

Other measures include improving *'safe vehicles'*, both motorcycles and motor vehicles, that prevent and reduce the severity of crashes. For motorcycles, these include Motorcycle Stability

Control (MSC), the Linked Braking System (LBS), the Anti-lock Braking system (ABS)[12] and traction control (VicRoads, 2015, Brown et al., 2015, BITRE, 2017a). Future safety developments may include airbags on new motorcycles, clothing and helmets. Furthermore, other motorised vehicles should be fitted with technologies that are able to sense motorcycles (and pedestrians and cyclists), alerting the driver of the presence of a motorcyclist who may be in a blind spot: Blind Spot Warning Devices (Centre for Road Safety, 2016). Vehicles should be designed to protect motorcyclists (and other vulnerable road users) at frequent impact locations (Brown et al., 2015). This includes bull bars and similar projections which negatively affect motorcylists. Brown et al. (2015) suggest measures such as limiting bull bar use in cities and regulating the design to be more forgiving if human contact occurs.

Motorcyclists should be encouraged to travel at *'safe speeds'*. This may mean travelling below the posted speed limit if conditions require it ('appropriate' speeds).

5.3 Counter measures in high-risk regional and remote areas

Because the number of crashes in regional and remote areas of WA is relatively low per unit area, postcodes were used as the unit of analysis. The crashes in the five highest risk postcodes were visually inspected. No dense clusters were located, although the following was observed:

- Larger number of crashes tended to occur in the regional towns (Albany, Bunbury and Geraldton) and remote towns (Broome and Kalgoorlie).
- It appears than more crashes in these towns occurred on the roads with higher speed limits (>50km/h). However, it is impossible to assess whether this is because higher volumes of motorcycles use these roads (greater exposure to risk) or if the higher speeds or riding style are responsible for this
- Several crashes occurred at large roundabouts and rotaries.

It is recommended that enforcement of helmet use as well as speed, alcohol and drug limits be stringently enforced in these regional and remote towns (*'safe road users'*).

[12] From November 2019, a new Australian Design Rule will be introduced mandating ABS in all new model motorcycles manufactured from this date AUSTRALIAN GOVERNMENT FEDERAL REGISTER OF LEGISLATION 2017. Vehicle Standard (Australian Design Rule 33/01 - Brake Systems for Motorcycles and Mopeds) 2017...

As well as recommendations relating to '*safe vehicles'* in metropolitan areas, it is recommended that the maintenance of high motorcycle volume roads and roadsides in the five higher risk regional and remote towns be prioritised (*'safe roads and roadsides'*). Maintenance of these roads should include maintaining skid resistance roads (for example, by retexturing or resurfacing) and pavement markings, sweeping, trimming trees, sealing joints, ensuring adequate drainage and street lighting (New Zealand Tranport Agency, 2017, VicRoads, 2014). Potholes, ruts and corrugation should be repaired as soon as possible, but warning signs should be used if repairs are delayed (VicRoads, 2014).

The placement of 'roadside furniture' (barriers, signs, median stripes, fences and trees) should be carefully considered to reduce both the risk of crash (by impairing visibility) and severity of any crash that might occur (when the motorcycles hit these objects) (VicRoads, 2014, Centre for Road Safety, 2016).

The affected roundabouts and rotaries should be examined with motorcycle safety in mind. Changes may need to be made in line with those discussed in Section 5.1.2, including ensuring that motorcyclists (and not only drivers of cars and trucks) slow down on the approach and within roundabouts, and improving the visibility of motorcyclists to other drivers (warning lights and signs). Traffic signals may need to be considered at high volume times.

6 RECOMMENDATIONS AND CONCLUSION

Recommendations were made based on the findings and recommendations of various Austroads and international documents (Milling et al., 2016, Brown et al., 2015, Steinmetz and Aumann, 2017, New Zealand Tranport Agency, 2017, VicRoads, 2014, Davoodi and Hossayni, 2015, de Rome et al., 2014, Centre for Road Safety, 2016) .

6.1 Recommendations relating to metropolitan intersections

<u>Infrastructure changes</u>

- Improving sight distance for cars and motorcycles for some intersections so that other road users are more easily able to see motorcyclists and motorcyclists have more time to take evasive action. These changes may include the removal or movement of roadside furniture and placement of objects such as poles within the intersection.
- Adapting car and truck sight distance within roundabouts so that motorcyclists are clearly visible but do not travel at too quickly, especially on the approach. For example, the entry angle should not be too low as this may block motorcyclists from view. Roundabout layout and curve radius of circulating carriageway should be clear from approach.
- Improved street lighting could also be used at high-risk intersections to improve visibility of motorcyclists.
- Warning signage and pavements markings could also be used to alert drivers to the intersection ahead and the presence of motorcycles. Fluoro backgrounds could be used to improve visibility of signs. Vehicle-activated signs can be used when volumes of traffic vary considerably at intersections.
- A motorcycle lane could be provided specifically at high-risk intersections, or lanes could be widened to allow motorcycles to filter to the front of the queue. Advance stop lines could be provided, allowing motorcyclists to stop ahead of other road users at the intersections and move off before them when the traffic signal changes.
- Traffic signal phases should be optimised to allow motorcycles to clear intersections. Traffic filter lights may be installed specifically to control right turning vehicles.

<u>Other recommendations</u>

- Motorcyclists should be encouraged to wear high visibility clothing including helmets in a colour such as white rather than black. Likewise, the colour chosen for motorcycles should ideally be more visible.

- Mandatory use of daylight running lights.
- Speed enforcement and the enforcement of drink and drug driving legal limits.

6.2 Recommendations relating to freeways

Infrastructure changes

- Improved sight lines, especially on roads with curves. This could include removal or moving of poles, vegetation or fixed objects which interfere with the line of sight and may reduce visibility of motorcyclists and making it more difficult for motorcyclists to take evasive action in potential conflict situations.
- Road surfaces should be optimised in high-risk, high motorcycle volumes sections of freeways. This would include skid resistant pavement markings, correcting road camber and improving drainage.
- The viability and effectiveness of exclusive motorcycle lanes, separated from the general traffic with a physical barrier or structure, needs further investigation but could be considered on high motorcycle volume parts of the Kwinana Freeway.
- Treatment of guard rails to protect motorcyclists from more severe injuries in the event of a crash along high-risk sections of the freeway, such as high volumes sections, especially around curves.

Other recommendations

- Encouraging the wearing of high visibility, protective clothing (helmets, jackets, gloves and footwear) to improve the conspicuity of motorcyclists and reduce injury severity in the event of a crash.
- Mandating the use of daytime running lights on all new motorcycles and the parking headlights of older motorcycles to improve visibility.
- Encouraging or mandating the use of automated safety technologies in new motorcycles including Motorcycle Stability Control, the Linked Braking System, the Anti-lock Braking system and traction control. Monitor new safety developments such as airbags on new motorcycles, improved clothing and helmets.
- Encouraging the uptake of sensing technologies in other motorised vehicles, particularly technologies able to sense vulnerable road users, including motorcyclists such as Blind Spot Warning Devices.
- Vehicles should be designed to protect motorcyclists at frequent impact locations. This includes bull bars and similar projections which negatively affect motorcyclists.

- Enforcing the speed limit, and encouraging the use of safe, appropriate speeds for the conditions. Enforcing drink and drug driving legal limits.

6.3 Recommendations relating to non-freeway metropolitan roads

Infrastructure changes

- Improving the condition of roads to reduce the risk of motorcycles crashes through interventions such as: sealing or repairing shoulders, improving surface drainage and use of anti-skid pavement markings. Other improvements to road surfaces and timely repairs to damaged surfaces should be undertaken.
- Removal of roadside hazards to improve sight distance.
- Improve street lighting in high-risk areas.

Other recommendations

- Improving conspicuity and reducing injury severity through the use of protective, high visibility clothing.
- Speed enforcement and the enforcement of drink and drug driving legal limits.
- Encouraging the uptake of technologies as discussed in Section 6.2.

6.4 Recommendations relating to regional and remote areas

Infrastructure changes

- Maintenance of these roads should include maintaining skid resistance roads (for example, by retexturing or resurfacing) and pavement markings, sweeping, trimming trees, sealing joints, ensuring adequate drainage and street lighting.
- Potholes, ruts and corrugation should be repaired as soon as possible, but warning signs should be used if repairs are delayed.
- The placement of 'roadside furniture' (barriers, signs, median stripes, fences and trees) should be carefully considered to reduce both the risk of crash (by impairing visibility) and severity of any crash that might occur.
- Motorcycle specific signage, raising awareness of dangers of the road to motorcyclists along windy stretches of road, for example '*crash zone for next .. km'*, or *'look for bikes'* signs.
- The installation of motorcycle friendly guard rails in higher volumes, windy routes, popular with recreational motorcyclists.

Other recommendations

- Speed enforcement and the enforcement of drink and drug driving legal limits.
- Improving conspicuity and reduce injury severity through the use of protective, high visibility clothing.
- Encourage the use of daytime running lights.

6.5 Strengths and limitations

This study examined the factors that increase the risk of a motorcycle crash, using a literature review and five years of crash data. Although there is a relatively small number of crashes (compared to those involving four- or more wheel vehicles), the use of five years of the most recently availably crash data strengthened the study. Because of the geographical spread of motorcycle crashes across the state, several methods of prioritising high-risk areas were chosen, rather than a single consistent method across all areas. Given the differences between the metropolitan area and regional and remote areas (population density, numbers of registered vehicles, differing road network characteristics), this was considered the most effective way of identifying high-risk areas for motorcyclists, although it limited comparisons between the metropolitan area and the rest of WA.

6.6 Conclusion

This study examined factors affecting risk of motorcycle crashes and identified areas with clusters of motorcycle crashes. Crashes tended to cluster at several large intersections (including interchanges) and along stretches of freeways in the Perth metropolitan areas. In regional and remote WA, higher numbers of crashes tended to occur in five towns. Recommendations were made to reduce risk of motorcycles crashes specific to each of intersections, metropolitan road sections, and regional and remote areas.

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