An investigation of serious injury motor vehicle crashes across metropolitan, regional and remote Western Australia

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Abstract
Previous research has identified that road crashes in the non-metropolitan area are significantly more likely to result in more severe injuries compared with those occurring in the metropolitan area. The aims of this study were twofold: to (i) review the published literature in regard to the factors associated with serious injury crashes across metropolitan and rural (regional and remote) areas, and (ii) to quantify and elucidate the risk of serious injury across Western Australia using police reported crash data for the period 2005-2009. Compared with crashes in the metropolitan area, crashes in the regional and remote area were 25%-50% more likely to result in an injury (any level) and two to three times more likely to result in either the death or hospitalisation of an involved road user. A range of crash, road, road user and behavioural issues were identified and discussed as contributing factors to the increased incidence of serious injuries in the regional and remote areas. This was followed up with a number of recommendations for further research in the areas of safer roads and roadsides, safer speeds, and safer road use and users.

Keywords
Road safety; motor vehicle crashes; serious injury; metropolitan, regional, remote area

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EXECUTIVE SUMMARY

Introduction

Road injury is a major public health concern throughout the world. Serious injuries are not only a financial burden but also a personal burden to those involved. Numerous studies have identified that the risk of crash involvement and the severity of injury varies with geographic location. In general, proportionally more crashes are recorded in urban or metropolitan areas while non-urban (regional and remote) area crashes are more likely to result in either the death or hospitalisation of an involved road user.

The aims of this investigation were two-fold. Firstly, to synthesise the understanding of factors that contribute to crashes of varying injury severity by location of occurrence, and secondly, to compare this understanding with that derived from the analysis of serious injury crashes across Western Australia. The specific objectives of the investigation were to:

- Critically review the published research literature to identify the range of factors associated with the occurrence of a serious injury motor vehicle crash by location of crash;
- Describe the epidemiology of serious injury crashes across metropolitan, regional and remote Western Australia and relevant risk factors through an analysis of police reported crash data;
- Compare and contrast the findings of the literature review with those obtained from the analysis of Western Australian crash data; and to
- Where warranted, provide recommendations for further research.

Method

For the literature review, a search of relevant databases including Google Scholar, ProQuest, Current contents, Scopus, Factiva and EconLit was conducted using 'key words' to identify local, national and international reports, referred journal articles and conference papers examining motor vehicle crashes by location of crash. The search was restricted to publications from 1990 onwards. For the analysis of Western Australian crash data, police records of all on-road motor vehicle crashes (both police attended/reported and road user reported) occurring during the period 2005-2009 in Western Australia were extracted by Main Roads Western Australia from their Integrated Road Information System (IRIS). After an initial set of analyses, the larger dataset of all police recorded crashes was reduced to those resulting in a 'serious injury' (defined as those resulting in the death or hospitalisation of an

involved road user). Factors associated with the distribution of serious injury crashes across the metropolitan, regional and remote areas of Western Australia were investigated. For the purposes of this study, the local government area of the crash reported in the IRIS database was assigned an Accessibility/Remoteness Index of Australia (ARIA) code and then categorised as metropolitan, regional and remote for analysis.

Summary of the main findings of the review of the literature

The literature review summarised the existing evidence on factors associated with serious injury crashes in different geographic locations (metropolitan, rural and remote areas). Factors reviewed include demographic, behavioural, road user, road and crash/vehicle characteristics. The main findings include:

Demographic factors

- Fatal and injury crash rates may be lower for metropolitan versus rural novice drivers up to two years post licensure.
- Males are more commonly involved than females in rural and remote area fatal and hospitalisation crashes.

Driver behavioural factors

- Speed compliance in Western Australia has been increasing since 2000 on both metropolitan and rural roads and in 2011 was noted (across all zones) to be higher on rural roads compared with metropolitan roads.
- In Western Australia in 2011, compliance was lowest on 60km/hour roads in the metropolitan area (51.8%) and 90km/hour zones in the rural area (59.9%).
- Speeding is estimated to be a contributing factor in up to 29% fatal crashes in remote WA compared with 26.5% of regional and 19% of metropolitan fatal crashes.
- Seat belt usage rates are lower among motor vehicle occupants in rural or remote areas than in metropolitan areas of WA.
- The proportion of motor vehicle occupants in WA killed or hospitalised due to a crash, not wearing a seat belt, increases with the ARIA remoteness index.
- The burden of road crash related injury associated with drink driving is disproportionately high in rural areas of Australia.
- Around 19% of rural/ remote drivers in northern WA report falling asleep at the wheel at least once.

- It has been estimated that fatigue is the primary contributing factor in 30% of fatal crashes on rural roads throughout Australia.

Road user type

- The majority of pedestrian crashes in Western Australia occur in metropolitan areas but rural and remote pedestrian crashes are more likely to result in death.
- Alcohol consumption by pedestrians may be an important risk factor in fatal pedestrian crashes in rural and remote areas.
- A significant proportion of fatal motorcycle crashes take place on rural and remote roads (34%).
- Little is known about the risk factors for bicycle crashes in rural and remote areas.

Road characteristics

- In Western Australia the majority of all reported crashes occur on straight roads. However, international evidence suggests that the risk of single vehicle crashes increases with the density of sharp bends in rural areas.
- The majority of fatal crashes occur on sealed roads in Australia. However, crashes in rural and remote areas are more likely to occur on unsealed surfaces compared with metropolitan areas.
- The majority of sealed roads with unsealed shoulders in WA are in rural and remote areas. Treatment of sealed shoulders is a highly effective method for reducing all-severity crashes, casualty crashes and the cost of crashes.
- The proportion of crashes in higher speed zones gradually increases as the ARIA remoteness indicator increases.

Crash and vehicle characteristics

- The majority (87%) of fatalities on rural and remote Western Australian roads are due to single-vehicle crashes. Single vehicle crashes have been found to commonly occur in high speed zones and on curved and unsealed roads and often have more severe outcomes than multi-vehicle crashes.
- Rural and remote environments constitute a mix of vehicle types including cars, buses, heavy trucks, agricultural vehicles, mopeds and bicycles and this diverse mix increases the likelihood of a crash in these road environments, though truck and heavy vehicle crashes are more common on rural versus metropolitan roads.

Conclusion

Fatal and serious injury crashes that result in hospitalisation are significant problems across metropolitan, rural and remote locations, including those in WA, with the risk of death and hospitalisation higher when crashes occur in the non-urban areas. This review identified several risk factors for crashes in these geographical regions and how they differ between regions. Existing evidence however, comes from several different sources internationally and nationally, using a wide variety of definitions for geographical regions and crash severity.

Summary of the main findings of the analysis of Western Australia crash data 2005-2009

Crash severity and location

- A total of 196,276 crashes were recorded by WA Police during the period 2005-2009.
- Approximately 82% of crashes occurred in the metropolitan Perth area, 12% in the regional area, and 6% in the remote areas of WA.
- Serious injury crashes involving either the death or hospitalisation of an involved road user totalled 11,874 and accounted for 6.1% of all crashes recorded during the study period.
- Minor injury crashes requiring medical treatment only constituted a further 13.8%, with the majority (80.1%) of crashes across the State resulting in only minor to major property damage.
- The majority of serious injury crashes occurred in the metropolitan area (67.8%), versus the regional (19.2%) and remote areas (13%). Serious injury crashes accounted for a significantly higher proportion of all crashes in the regional (9.6%) and remote (14%) areas, compared with the metropolitan area (4.9%).
- Compared with crashes in the metropolitan area, a crash in the regional and remote area was respectively 25% and 50% more likely to result in an injury (any level) to an involved road user, and two to three times more likely to result in either death or hospitalisation (i.e., serious injury).
- Serious injury crashes were three to 4.5 times more likely to result in the death *versus* hospitalisation of a road user when occurring in the regional and remote areas relative to the metropolitan area.

Univariate analysis of crash, road, road user and vehicle factors

- Multivehicle crashes involving right turn-right thru manoeuvres, particularly at intersections, were the predominant metropolitan crash type, whereas single vehicle

run off road hit object and roll-over crashes were the predominant crash type in regional and remote areas.

- When vehicles were involved in hit object collisions they most commonly collided with trees and embankments in the regional and remote areas compared with kerbs, trees and traffic islands in the metropolitan area. Very few vehicles in any area collided with an identified roadside barrier.
- Around six in ten serious injury crashes in the metropolitan area occurred on roads with posted speed limits of 60km/hour or less, while the majority of serious injury crashes in regional (46.5%) and remote areas (62.1%) occurred on roads with the maximum posted speed limit (110km/hour).
- The proportion of crashes occurring on unsealed roads was substantially higher in the remote area (21.9%) and slightly higher in the regional area (7.7%), compared with the metropolitan area (0.5%) of WA.
- Crashes on curved sections of road were twice as likely in the regional (35.8%) and remote areas (32.4%) of WA, compared with the metropolitan area (17.6%).
- Around two-thirds of serious injury crashes in the metropolitan area occurred on local government owned roads compared with just under 50% for the regional and remote areas. However, local government was the predominant owner of *unsealed* crash involved roads in the regional and remote areas.
- Approximately 25,798 road users were involved in the 11,874 serious injury crashes, with three-quarters being drivers. Passengers accounted for one-quarter to four in 10 involved road users in the regional and remote areas and 16% in the metropolitan area.
- For drivers who were injured, they were approximately three times as likely to be killed in regional and remote area crashes compared with metropolitan area crashes.
- Males accounted for two-thirds of all seriously injured drivers, with this figure being higher in the regional (68.4%) and remote areas (71.4%) compared with the metropolitan area (65%).
- Across all locations, 79.7% of seriously injured drivers/riders held a full licence, with a further 11.1% holding a provisional licence. In the remote area, 6.9% of the driver/ riders were unlicensed, 4.9% had a cancelled licence and 3.9% had a suspended licence.

- Across all locations males and younger age drivers were more likely to be driving without a valid licence, with the risk for these factors being greatest for regional and remote area crashes compared with the metropolitan area crashes.
- Drivers/riders involved in a serious injury crash in metropolitan Perth were less likely to record a positive Blood Alcohol Concentration Level (BACL) (11.2%) compared with those in regional (16.5%) and remote areas (23.4%). Overall, 51% of the drivers/riders testing positive for alcohol recorded a BACL exceeding 0.100gm%, with this figure being highest in the remote area (63.7%).
- Across all locations, crash involved males, younger age drivers/riders and unlicensed drivers/riders were significantly more likely to be record a positive BACL, with some variation in the risks associated with these factors across the locations.
- Just under 6% of all crash involved drivers/riders were recorded to be not wearing protection (seat belt or helmet), with this figure highest for those crashing in the regional (7.6%) and remote areas (15.6%), compared with the metropolitan area (4%).
- Males and those recording a positive BACL across all areas were significantly more likely to be unprotected at the time of the crash. Unlicensed drivers/riders crashing in the metropolitan and remote areas were also significantly more likely to have not used protection. Variation in the risks associated with these factors was noted across the locations.
- Passengers involved in a serious injury crash were significantly more likely to be killed in the regional (6.7%) and remote areas (7.8%), compared with the metropolitan area (2.5%).
- Passengers injured in remote area crashes were three times more to have not used protection (33.8%) than passengers injured in regional (10.9%) and metropolitan (8.4%) area crashes.
- Serious injury crashes involving pedestrians were most likely to occur in the metropolitan area (77.3%) and in most cases resulted in hospitalisation only.
- Pedestrians were more likely to be killed in crashes occurring in the regional (13.3%) and remote (17.4%) areas compared with the metropolitan area (7.4%). This may be due to a higher proportion of pedestrian crashes occurring in high speed zones (≥80km/hour) in the regional and remote areas.

- Trucks were more frequently involved in serious injury crashes in the regional and remote areas, while bicycles were more frequently involved in serious injury crashes in the metropolitan area.
- Motorcycles and their derivatives were consistently represented in crashes across the locations though the nature of their crashes varied. They were more often involved in multiple vehicle crashes in the metropolitan areas and more likely to be involved in single vehicle crashes in the regional and remote area.

Multivariate analyses of crash/road and road user factors

- Compared with the metropolitan Perth area, serious injury crashes in the *regional and remote* areas were significantly more likely to involve a single vehicle rather than multiple vehicles/units (OR=1.65 ^{regional}; OR=3.0 ^{remote}), to occur on unsealed rather than sealed roads (OR=6.51 ^{regional}; OR=19.0 ^{remote}), on curves rather than straight sections of road (OR=2.15 ^{regional}; OR=2.35 ^{remote}) and on roads with posted speed limits of ≥90km/hour compared with ≤80km/hour (OR=9.21 ^{regional}; OR=12.01 ^{remote}).
- Compared with the metropolitan area, increased odds of involvement in a serious injury crash in the *remote* area were identified for male drivers (OR=1.25); drivers aged 25-39 years (OR=1.43); drivers recording a BACL of ≥0.101gm% (OR=2.54), 0.05gm%-0.100gm% (OR=1.54) and 0.001gm%-0.49gm% (OR=1.48), and drivers who did not hold a valid licence at the time of the crash (OR=2.13).
- Compared with serious injury crashes in the metropolitan area, increased odds of involvement in a serious injury crash in the *regional* area were identified for drivers aged 40-59 years (OR=1.36) while drivers aged 17-24 years showed reduced odds of crashing (OR=0.86). All positive BACL were associated with an increased odds of crashing in the regional area: ≥0.101gm% (OR=1.72); 0.05gm%-0.100gm% (OR=1.70), and 0.001gm%-0.049gm% (OR=1.55). Driver sex and driver licence status were not significantly associated with serious injury crashes in the regional area.

Summary discussion

As noted in other studies, a significant relationship was identified between the location of the crash and the injury severity of the crash. Calculation of the odds associated with being injured (any level), seriously injured, and killed showed that compared with crashes in the metropolitan area, non-urban area crashes, and particularly those in the remote area, entail a higher risk of injury and more severe injury. Notwithstanding this finding, the majority of the

road injury burden, because of the absolute numbers of road users injured, can be attributed to crashes within the metropolitan area.

The findings of the study can be discussed in relation to safer roads, safer speeds, safer vehicles and safer road use and users. In relation to safer roads, there is a clear need to continue the existing micro analysis of metropolitan intersection with a high incidence of serious injury crashes because of the identified higher contribution of crashes in these environments to serious injuries in metropolitan Perth. In contrast, in the regional and remote areas of Western Australia it is imperative that roads are treated using known effective initiatives to reduce the comparatively high incidence of single vehicle run off road crashes which are a significant feature of the serious injury crashes in these locations. This finding was consistent with that identified in the review of the published literature. Treatment of the non-urban area roads to reduce run off road crashes is a responsibility for the State and the local government sector, which together share and ownership of the non-urban area roads on which these serious injury crashes occur.

Whilst it was not possible to investigate the role of illegal speeding in the serious injury crashes examined, there was reasonable evidence to conclude that speeding is strongly implicated in the higher incidence of serious injury crashes in regional and remote WA. This concurs with previous research which has identified a higher incidence of serious injury crashes in higher speed zones in the non-urban area. Thus, limiting travel speeds in the non-urban areas to those that are within biomechanical tolerances in the event of a crash is essential, particularly if the road does not have the necessary treatments and infrastructure to manage crash forces and limit injury severity. The higher incidence of serious injury crashes on unsealed roads in the regional and remote area also suggests that open speed limits on these roads be reduced to limit loss of control/run off road crashes. In addition to addressing the appropriateness of speed limits on non-urban area roads, attention must be given to how best to enforce existing speed limits in these locations. To this end the program of enhanced speed enforcement being implemented by WA. Police is an important initiative in reducing speed related crashes across the State and particularly on regional and remote areas roads which are often ‘under enforced’.

As with other studies of non-urban area crashes, trucks were more likely involved in serious injury crashes in regional and remote area crashes, which is perhaps due to the greater exposure of these vehicles to these roads. Heavy vehicle use and particularly long haul

transport is known to represent a considerable crash risk for a variety of work, environment and driver related reasons. A better understanding of the potential crash risk factors for trucks and heavy vehicles in the non-urban area may be derived from the nation-wide investigation of heavy vehicle crashes that is soon to be concluded. The higher incidence of single vehicle crashes in the non-urban area also underscores the importance of increasing the uptake of vehicles with technologies such as electronic stability control and traction control that will reduce the incidence of loss of control, run off road crashes.

This study noted a number of significant findings in relation to the behaviour of drivers in the regional and remote area that can potentially explain their higher involvement in serious injury crashes. In general, drivers involved in crashes in these areas, compared with those crashing in metropolitan Perth, were more likely to have recorded a higher level of Blood Alcohol Concentration, to be unlicensed, and to not have worn a seat belt. This pattern of unsafe, risky behaviour may be due to a perceived and/or actual lower likelihood of detection and greater community tolerance of such behaviours. Male drivers were more likely than female drivers to engage in such behaviours. Consequently there is a strong need to understand the factors contributing to such risk behaviours and how best to intervene to reduce the contribution of these factors to serious injury crashes in the non-urban area.

In summary, it is reasonable to conclude that a combination of road, environment, speed, and road user behaviours are likely contributing factors to the higher incidence of serious injury crashes in regional and remote WA. That said the findings of the study are tempered by the use of police reported data and not linked data which would confirm the injury outcomes of involved road users. Furthermore, the examination of contributing factors was limited by the unavailability of other driver behavioural factors such as fatigue and illegal speeding and information on the crash worthiness of involved vehicles. Most importantly the study was not able to examine the role of post-crash care and how this may be a contributing factor to the higher incidence of fatal injuries among non-urban area crashes as has been observed elsewhere.

Recommendations

This study noted a range of safer roads, safer speeds, safer vehicle, and safe road use factors that go some way towards explaining the identified variation across Western Australia in the distribution of serious injury crashes. It is clear however, that additional research is required using a variety of methods to further elucidate the causes of and potential countermeasures for

serious injury crashes across WA. The following recommendations for future research were developed after consultation with the WA Office of Road Safety.

Safer Roads and Roadsides

1. *Expansion of the Main Roads WA micro analysis of serious injury crashes at metropolitan intersections to further investigate the contribution of road and driver factors to crashes at intersections.*

   This study noted that one in five serious injury crashes in the metropolitan area occur at intersections, with around four in ten serious injury crashes involving vehicles colliding at right-angles. The first tranche of 20 metropolitan intersections investigated by the micro-analysis noted a number of potential contributing factors and made recommendations for cost-effective treatments. It is recommended that the micro-analysis be extended to the next 20 intersections for serious injury crashes.

2. *Further research to identify new and innovative treatments for metropolitan intersections.*

   To complement Recommendation 1, it is recommended that further research be undertaken to identify new and innovative treatments for metropolitan intersections, including signalised and non-signalised intersections. This work should also include proposals for the development, implementation and evaluation of trials of innovative measures to create Safe System intersections.

3. *In-depth analysis of the factors contributing to run off road crashes and treatments to reduce the incidence of and injury severity.*

   This study noted that single vehicle run off road crashes accounted for around one-quarter of serious injury crashes in the metropolitan area and nearly 60% and 70% respectively of serious injury crashes in the regional and remote areas. Further to this, around a third of run off road crashes in the regional and remote areas occurred on curves, with most run off road crashes across all three areas resulting in the collision with an object other than a designated barrier. On the basis of these findings it is recommended that a micro-analysis style project be developed to identify and review roads with a high incidence of run off road events to investigate potential contributing crash and injury factors and appropriate cost-effective countermeasures by location. This project can also draw on the findings from two current C-MARC projects: the

epidemiology of single vehicle run off road crashes in metropolitan Perth, and, a review of initiatives to improve curve delineation.

Safe Speeds

4. *Identify and audit high crash risk roads in the regional and remote locations to determine the appropriateness of the current speed zone and need for rezoning.*

Though this study was not able to investigate the contribution of excess or inappropriate speeds to serious injury crashes across Western Australia, there was some evidence to support previous research identifying a relationship between crashes in higher speed zones (90km/hour and higher) and serious injury outcomes for the regional and remote area. At issue is whether the roads on which these crashes have occurred are appropriately speed zoned for their condition and level of infrastructure (e.g., sealed roadway and shoulders; edge lining; clear zones; barriers; median to separate vehicles). It is therefore recommended that further research be undertaken to identify and audit high crash risk roads in the regional and remote areas to determine the appropriateness of the posted speed limit and make recommendations where appropriate for a lowering of the speed limit to reduce the risk of crashing and serious injury.

Safe Road Use and Users

5. *Undertake an in-depth investigation of unlicensed driving in the remote areas of Western Australia.*

Drivers involved in serious injury crashes in remote Western Australia were twice as likely as those crashing in regional WA and metropolitan Perth to be unlicensed (i.e., not holding a current, valid licence at the time of the crash). It is therefore recommended that a program of both quantitative and qualitative research be undertaken to address the following issues:

- the extent of unlicensed driving;
- persons at risk of unlicensed driving;
- factors associated with the failure of remote areas residents to obtain and maintain a valid motor vehicle drivers' licence and drive unlicensed; and,
- a review of the effectiveness of existing systems and programs in remote Western Australia to promote licensure.

The research should also consider how best to (i) engage remote communities to take responsibility for the problem of unlicensed driving and to reduce the incidence of; (ii) the provision of alternate modes of transport other than private vehicle use, and (iii) more strategic detection and enforcement initiatives and appropriate penalties (i.e., vehicle impounding; wheel clamping;) for unlicensed driving.

6. *Undertake an in-depth investigation of the use of alcohol and drink driving in remote and regional Western Australia.*

Around 13% of drivers involved in a serious injury crash tested positive (non-zero) for alcohol; this proportion was greatest in remote Western Australia (23.4%) compared with regional WA (16.5%) and metropolitan Perth (11.2%). Even more concerning was the finding that three-quarters of remote area drivers and 60% of regional area drivers who tested positive recorded a BAC $\geq$ 0.08gm%. Understanding the unique area-specific factors that predispose non-urban area drivers to drink drive and the development of relevant countermeasures is thus warranted. Both quantitative and qualitative methods should be used to investigate the range of factors associated with the use of alcohol in non-urban areas and compliance/non-compliance with drink-driving legislation, in particular:

- the extent of drink driving;
- persons at risk of drink driving;
- the range of individual, sociocultural and community-wide factors that support or inhibit drink driving;
- access to alcohol and alternative means of transport;
- current detection and enforcement practices and the appropriateness of penalties for non-urban area residents; and,
- how best to reduce the incidence of alcohol impaired driving.

7. *Undertake an in-depth investigation of the non-use of seat belts by motor vehicle occupants in remote areas of Western Australia.*

Seat belt use can significantly reduce the risk of serious injury in the event of a crash and yet in this study remote area drivers (inclusive of helmet use by riders-15.6%) and passengers (33.8%) were considerably more likely to be unbelted compared with those involved in crashes in metropolitan Perth and even regional WA. At present there is no contemporary evidence of the prevalence of and risk factors for the non-use of seat

belt across Western Australia using observational (as opposed to crash) data. Given the level of non-use identified in this study among remote area motor vehicle occupants there is a need for research using a mix of quantitative (observational data) and qualitative methods to understand:

- the prevalence of use and non-use of seat belts and other restraints among remote area motor vehicle occupants;
- persons at risk of being 'unrestrained';
- the range of individual, vehicle, sociocultural (particularly Indigenous issues) and community-wide factors that support or inhibit appropriate restraint use;
- current detection and enforcement practices and the appropriateness of penalties for remote area residents; and
- how best to increase the use of seat belt by drivers and passengers.

8. *Detailed examination of the pattern of pedestrian injury crashes in regional and remote Western Australia.*

   The majority of pedestrians killed or hospitalised state-wide were involved in crashes in the metropolitan area, though the risk of being fatally injured was greatest for pedestrians involved in crashes in the regional and remote location. This is perhaps because of their greater likelihood of being hit whilst using roads with higher posted speed limits and the lack of facilities for safe walking. Given the higher risk of fatal injury for pedestrians, the is good reason to undertake a detailed examination of the high risk localities in regional and remote Western Australia to determine the circumstances and risk factors for pedestrian crashes so as to develop appropriate and effective counter measures in relation to engineering and road user behaviour initiatives.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

Road crashes cause serious injuries, loss of life and damage to infrastructure. According to the World Health Organization (WHO, 2009), approximately 3500 people die every day and millions are injured or disabled every year worldwide due to road crashes. More than 50 % of people who die in road crashes are aged between 15 and 44 years (WHO, 2004) and millions of others sustain injuries or suffer major disabilities. This is significant in terms of potential years of life lost and quality adjusted life years. In Australia, four people die and 90 people suffer a serious road injury every day (Australian Transport Council, 2011) (ATC), with the cost of the problem estimated to be $27 billion annually (Bureau of Infrastructure, Transport and Regional Economics, 2006). Even though there has been a significant decline in the number of road crash related fatalities on Australian roads, less progress has been made towards reducing the number of non-fatal serious injuries in the past decade (ATC, 2011).

As shown in Figure 1.1, the road crash fatality rate for Western Australia has also gradually declined from the peak rates of the late 1960's and early 1970's but also shows evidence of flattening in more recent years. In 2007, Western Australia (11.2 deaths per 100,000 population) was ranked worse than only the Northern Territory (27/100,000 pop.) in terms of road deaths and had a road death rate substantially higher than the Australian rate of 7.6 deaths per 100,000 population (Thompson & Hill, 2010).

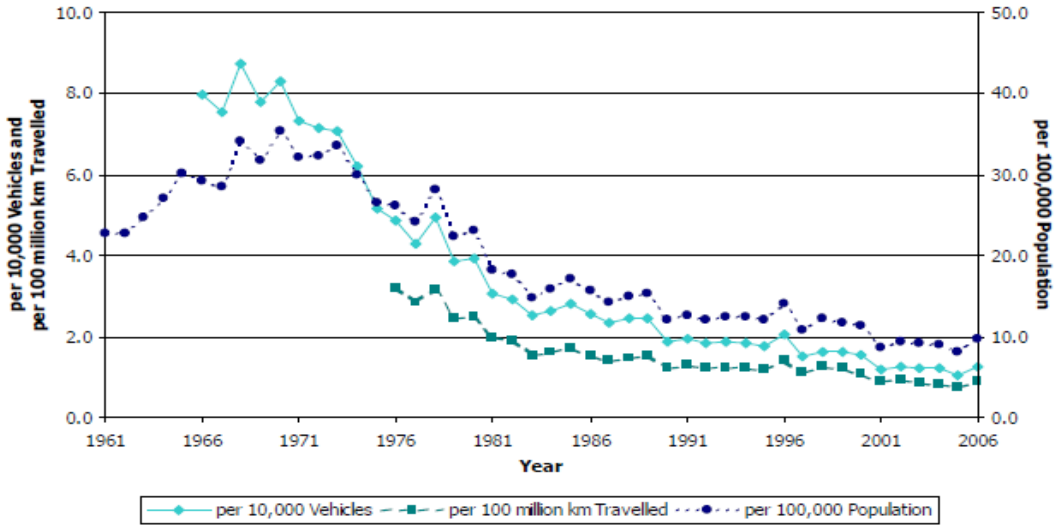

Figure 1.1 Road crash fatality rate; Western Australia 1961-2006

1.1 Crashes by geographic location

The characteristics of road crash related deaths and serious injuries are known to vary with the location of the crash. Epidemiological analyses of the distribution of motor vehicle crashes elsewhere have found that fatal injury crashes occur more commonly in non-urban or rural areas while crashes resulting in non-fatal injuries more commonly occur in urban or metropolitan areas (Elvik, Vaa, Hoye, Erke & Sorensen, 2009; Peden et al., 2004; Zwerling et al., 2005). The explanations that have been offered for this pattern include road design, proximity to emergency medical services, human factors (Rakauskas, Ward, & Gerberich, 2009) and high travel speeds (ATC, 2011).

The National Road Safety Strategy 2011-2020 noted that outer regional and remote areas of Australia evidence higher incidences of crashes in comparison to the metropolitan areas (ATC, 2011). Table 1.1 presents the distribution of fatal crashes in Australia by remoteness index for the period 2002-2006. Fatal crashes were significantly higher in the outer regional and remote areas when the population of these areas were taken into account (ATC, 2011). In WA, nearly one-quarter of fatal crashes occurred in the remote and very remote areas, which was second only to the Northern Territory (67% of fatal crashes).

Table 1.1 Distribution of fatal crashes by remoteness index; Australia 2002-2006

ARIA+ Region	Australian Jurisdiction								
	NSW %	VIC %	QLD %	SA %	WA %	TAS %	NT %	ACT %	AUS %
Major Cities	35	40	29	38	36	0	0	88	34
Inner Regional	28	40	33	27	21	37	0	7	30
Outer Regional	15	13	23	23	17	50	29	0	18
Remote	1	1	7	5	9	10	23	0	4
Very Remote	1	0	4	5	14	1	44	0	4
Unknown	20	6	4	1	3	2	4	5	9

Source: ATC (2011)

In 2006, the majority of road crashes occurred in the metropolitan area of WA, seriously injuring 2,768 people (Marchant, Hill, Caccianiga & Gant, 2008). In comparison to the previous five year average, there was an overall increase in the total number of rural (16%) and metropolitan (19%) fatal crashes in 2006

(Meuleners, 2007). The author also reported an increase in the number of fatal rural crashes in 2006 compared to the previous five year average in all regions of Western Australia except for the Gascoyne, Kimberley, Great Southern and Wheatbelt North regions. A rise in the proportion of fatal crashes in 2006 was particularly evident in the Wheatbelt South (61%) and the South West (67%) regions, compared to the previous five years. A noteworthy decline in the number of fatal crashes in 2006 compared to the previous five year average was found in the Kimberley (-31%) and Wheatbelt North (-26%) regions (Meuleners, 2007).

Three other reports affirm the relationship between location of crash and injury outcome in Western Australia. Over the period 1999-2010, approximately 58% of road user deaths occurred on rural roads compared with 42% on metropolitan Perth roads (Office of Road Safety, 2011). In contrast, the majority of crashes resulting in hospitalisation in 2006 occurred in metropolitan Perth compared with rural Western Australia: 69% versus 31%. (Marchant et al., 2008). Finally, other evidence from a population based study by Fatovich, Phillips, Langford and Jacobs (2011) utilising data from Royal Flying Doctor Service (RFDS) database, Australian Bureau of Statistics (ABS) and Western Australia's trauma registry, found a direct relationship between remoteness of road crashes and the fatality rate during the period 1st July 1997 to 30th June 2006.

1.2 Aims and objectives

Whilst many studies have described the epidemiology and characteristics of crashes by regional location (e.g., Tziotis, Roper, Edmonston, & Sheehan, 2006), there have been few reviews investigating how contributing factors to injury outcomes might systematically vary by crash location and the relative risks of these factors. Understanding how the factors associated with a serious casualty crash vary with the regional location of the crash can provide useful information for the development of region-specific countermeasures.

The aims of this investigation were two-fold. Firstly, to synthesise the understanding of factors that contribute to crashes of varying injury severity by location of occurrence, and secondly, to compare this understanding with that derived from the analysis of serious injury crashes across Western Australia. The specific objectives of the investigation were to:

- Critically review the research literature to identify the range of factors (e.g., driver, vehicle and road factors,) associated with the occurrence of a serious injury motor vehicle crash;
- Determine whether the factors associated with a serious injury crash vary with the regional location of the crash;
- Describe the epidemiology of serious injury crashes across metropolitan, regional and remote Western Australia and relevant risk factors through an analysis of police reported crash data;
- Compare and contrast the findings of the literature review with those obtained from the analysis of Western Australian crash data; and to
- Where warranted, provide recommendations for further research.

2. METHOD

2.1 Ethics approval

This research was undertaken with the approval of the Human Research Ethics Committee of the School of Public Health, Faculty of Health Sciences, Curtin University (approval SPH-38-2011).

2.2 Literature search and retrieval

A critical review of the scientific literature published in Australia and elsewhere was undertaken to:

- define the nature of serious injury motor vehicle crashes;
- identify the range of driver, vehicle, and road variables associated with serious casualty crashes; and
- explore how serious injury crash factors vary with the regional location of the crash.

A literature search of databases including Google scholar, ProQuest, Current Contents, Scopus, Factiva and EconLit was undertaken using 'key words' to retrieve local, national and international publications (books, reports, scientific journal articles, conferences papers) relevant to the topic. The inclusion criteria for the literature search were as follows:

- information on crashes occurring on public roads;
- crashes where the resulting injury involved the death or hospitalisation of a road user;
- crashes involving at least one motorised vehicle (i.e., cars, truck, buses, motorbikes etc); and
- publications from 1990 onwards.

2.3 Western Australian motor vehicle crashes

Police records of all on-road motor vehicle crashes (both police attended/reported and road user reported) occurring during the period 2005-2009 in Western Australia, were extracted by Main Roads Western Australia from their Integrated Road Information System (IRIS). After an initial set of analyses, the larger dataset of all police recorded crashes was reduced to those resulting in a 'serious injury' to

investigate the factors associated with their distribution across the metropolitan, regional and remote areas of Western Australia. A discussion of the nature of serious road injury crashes and its application in this study follows.

2.3.1 Definition and selection of serious injury motor vehicle crashes

Even though there is a clear definition of fatality, some jurisdictions find it problematic to define a serious injury. Many jurisdictions define serious injury based on police crash reporting (D'Elia & Newstead, 2010). In Victoria the definition of serious injury is based on a combination of being taken to the hospital and being admitted in a hospital after a crash. This hospital admission status is validated through follow up from various sources of data. In Western Australia, the designation of a crash involving a serious injury relies initially on police reports in relation to the *death* or *hospitalisation* of the crash involved road user. This outcome is represented in the IRIS database under the 'Severity' variable and relates to the *highest level of injury* sustained by a crash involved road user.

Other measures of serious injury related to the Abbreviated Injury Scale (AIS) and the Injury Severity Score (ISS) and the International Classification of Diseases Injury Severity Score (ICDISS) have been recently proposed to address the shortcomings of police reported information

Abbreviated Injury Scale – Injury Severity Score

The AIS is a specialised classification of injuries that is based mainly on anatomical descriptors of the resulting tissue damage from an injury (D'Elia & Newstead, 2010). It has two parts, namely the injury descriptor and a range of severity scores on a scale of 1-6, assigned to each injury descriptor. The AIS is a measure of severity for a single injury. ISS is derived from AIS and aims to combine multiple injuries in order to create a single combined score for each patient (D'Elia & Newstead, 2010).

International Classification of Diseases Injury Severity Score

Due to the proprietary nature of the AIS, researchers have developed an empirically derived measure of severity based on ICD (International Classification of Diseases) diagnoses and short term outcomes such as hospital mortality coded along with the ICD system (D'Elia & Newstead, 2010). ICISS is one of the empirically derived measures of injury severity. This approach to assessment of serious injury is based on the calculation of Survival Risk Ratios (SRRs) for each ICD code. The SRRs are

calculated by dividing the number of patients that survive a given ICD injury diagnosis code by the number of patients with that diagnosis code (D'Elia & Newstead, 2010). ICISS is the product of the SRRs corresponding to a patient's set of injuries.

In Western Australia there is a well-established practice of linking population-wide police crash reports, hospital admission records and death registrations (Lopez, Rosman, Jelinek, Wilkes, & Sprivulis, 2000). Crashes reported by the police have been linked to hospital admission records enabling the direct calculation of ICSS (D'Elia & Newstead, 2011). Reliable information on injury outcomes is essential for the evaluation of road safety countermeasures and interventions. For this reason, linkage of crash details in police crash reporting systems with injury details in hospital records makes the best use of both data sources (Lopez et al., 2000). However a linked database has its limitations that need to be understood. There are problems of comprehensiveness, precision and consistency associated with the use of routinely collected data, whether from police, hospital, ambulance or insurance sources. There is also the possibility that some records are incorrectly matched. Probabilistic matching of records can result in links that are either 'false positives' or 'false negatives' (Rosman, 2001).

For a range of pragmatic reasons, and noting the on-going work by the Data Linkage Branch of the Health Department of Western Australia to develop a more meaningful measure of serious injury, a serious injury crash for this project was considered to be one which resulted in the police reported *death* or *hospitalisation* of a crash involved road user. These crashes were identified in the IRIS database via the Severity variable: 1=Fatal; 2=Hospitalisation. It should be noted that the hospitalisation of the road user was not verified through the identification of and link with a corresponding Health Department of Western Australia (HDWA) hospitalisation record and thus may be a less than valid measure of hospitalisation. This is because previous investigations have shown that less than half of hospital admission records for a road traffic casualty actually link to a corresponding police crash report (Rosman, 2001).

2.3.2 Classification of the location of serious injury motor vehicle crashes

The Accessibility/Remoteness Index of Australia (ARIA) (Department of Health and Aged Care, 2001) represents one measure of geographic remoteness across Australia

and physical distance by road to the closest urban centre. The ARIA presents five categories of remoteness ranging from Highly Accessible, Accessible, Moderately Accessible, Remote, and Very Remote. These categories can be used to classify Western Australia into areas defined as metropolitan, regional and remote. In general, the metropolitan area of Perth consists of Highly Accessible and Accessible areas, while areas outside of metropolitan Perth with an ARIA index of Accessible and Moderately Accessible are classified as regional Western Australia. Remote and Very Remote areas are classified as remote Western Australia (Marchant et al., 2008).

For the purposes of this study the local government area of the crash reported in the IRIS database was assigned an ARIA code and then categorised as metropolitan, regional and remote for analysis.

2.3.3 Data management and analysis

Motor vehicle crash data extracted from the IRIS database were imported into SPSS (Version 19) for management and analysis. Descriptive and multivariate analyses (using binary logistic regression and multinomial logistic regression) were undertaken of crash and person level serious injury data. The pattern of serious injury crashes across the metropolitan, regional and remote areas of Western Australia was described and the risk factors for the occurrence of serious injury crashes and other driving outcomes modelled.

3. LITERATURE REVIEW

This literature review discusses the existing evidence on factors associated with serious injury crashes in different geographic locations (metropolitan, rural and remote areas). Factors reviewed include demographic, behavioural, road user, road and vehicle-crash characteristics.

3.1 Demographic factors

3.1.1 Age

Although road injury affects all age groups, it is a leading cause of death globally for those aged 15-29 years, particularly drivers (WHO, 2009). Numerous studies have shown that in comparison to other drivers, drivers aged less than 25 years, are more likely to be involved in crashes and have higher casualty rates in the event of a crash (Ryan, Legge & Rosman, 1998; McGwin & Brown, 1999). In Australia, drivers aged 17-25 years are similarly over-represented among driver fatalities. For example, in 2008 they accounted for 25% of driver fatalities while representing only 15% of total licensed drivers (ATC, 2009).

Some evidence suggests that crash risk for younger drivers varies with geographical location of residence or crash, more so than for other drivers. Analysis of Australian and New Zealand crash data for the period 1999-2003 by Tziotis et al. (2006) identified that young driver (under 25 years), particularly males, were more likely to crash on rural and remote roads. In another study of nearly 1,700 provisional drivers in WA, it was noted that drivers in the metropolitan area were slightly more likely than those in rural areas to be involved in a police reported crash in their first year of licensure (Stevenson & Palamara, 2001). Location of residence however, was not significantly associated with crash involvement after adjusting for a range of other demographic and socio-cultural factors. The authors cautioned that a higher level of under-reporting of non-casualty crashes to police by rural drivers may have undermined the validity of the findings (Stevenson & Palamara, 2001).

In contrast, a study of provisional drivers in NSW found that fatal and injury crash rates were significantly lower for metropolitan versus rural novice drivers up to two years post licensure (Chen et al., 2009). While young drivers in the metropolitan area also had an elevated risk of crashes compared to other drivers, novice drivers in rural areas had a much higher rate of involvement in single vehicle crashes (Chen et al.,

2009). The elevated risk of crashes for young drivers in rural areas may be due to factors including road infrastructure, road alignment and speeding.

3.1.2 Gender

In Australia, males accounted for two-thirds (66%) of serious injury road crashes in 2006–07 (Henley & Harrison, 2009). Male rates of serious injury due to crashes were approximately twice the rate observed for females in each remoteness area (Henley & Harrison, 2009). In addition, another study found that the male crash fatality rate in rural and remote areas of Australia was significantly higher than the male fatality rate in metropolitan areas (Veitch, 2009).

In WA, males accounted for 61% of persons killed or hospitalised due to crashes in the rural areas and 57% in the metropolitan area in 2006 (Marchant et al., 2008). When compared to the 2001 to 2005 average, the overall number of male crash fatalities in 2006 in WA increased by 26%, compared to a marginal decrease in female fatalities of 6% during the same period (Meuleners, 2007).

Risk-taking behaviour has been recognised as a possible explanation for the higher incidence of motor vehicle crashes among male drivers (Turner & McClure, 2003).

3.2 Driver behavioural factors

3.2.1 Speed

Speeding is an important contributing factor to the occurrence and severity of crashes. Higher travelling speeds allow drivers less time to respond to hazards and increase the level of energy involved in the event of a crash. (Marchant et al., 2008). According to WHO (2009), a 5% increase in average speed is related to a 10% higher risk of crashing and a 20% higher risk of a fatality. In addition, pedestrians have more than a 90% chance of surviving a crash at 30km/hour but less than a 50% chance of surviving a crash at 45 km/hour (WHO, 2009).

According to the ATC (2011), speeding accounts for 34% of fatal and 13% of serious injury crashes in Australia. In WA, speed was considered to be a factor in 24% of all road crash fatalities in 2010, with the proportion being highest in the remote area (29%) versus the regional (26.5%) and metropolitan (19%) (Hill, Thompson, Yano & Smith, 2012). Earlier studies have shown that 52% of passenger fatalities and 16% of hospitalisation crashes involve speed as a contributing factor (Marchant, et al., 2008).

Among young adults aged 17-24 years killed or hospitalised due to a crash, speed was found to be a factor in over 32% of crashes (Marchant et al., 2008). In addition, there was an 18% increase in speed-related road crashes in 2006 in WA compared to the previous five year average (Figure 3.1) (Marchant et al., 2008).

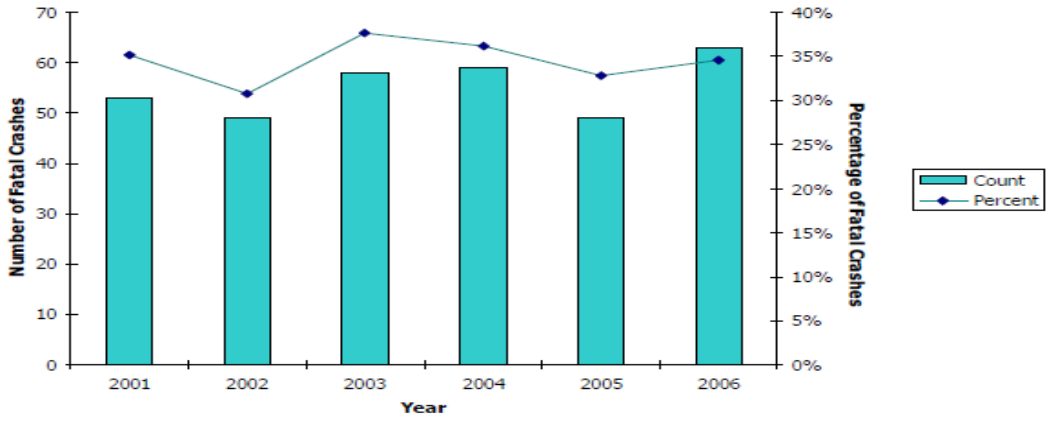

Figure 3.1 Fatal crashes attributed to speed; Western Australia, 2001-2006 (Marchant, et al., 2008).

Periodic surveys of vehicle travel speeds across the Western Australian metropolitan and rural road networks shows that the proportion of speed compliant vehicles varies with geographic location and posted speed zones. Overall, the proportion of vehicles complying with the posted limit (all zones) increased in both locations since 2000 with the greatest percentage increase in the rural area (9.8%) versus the metropolitan (6.8%) (Radalj & Sultana, 2012a; Radalj & Sultana 2012b). In 2011, compliance was lowest on 60km/hour roads in the metropolitan area (51.8%) (Radalj & Sultana, 2012b) and on 90km/hour roads in the rural area (59.9%) (Radalj & Sultana, 2012a). Though speed compliance appears greater on Western Australian rural roads versus metropolitan roads, speeding is typically considered more common on rural roads due to low traffic volumes, sparse roadside development and perceived lower likelihood of being detected by police. Indeed Tziotis et al. (2006) concluded that speed was a significant factor in crashes on rural and remote Australian and New Zealand roads.

3.2.2 Seat belt use

Worldwide, there is a highly significant negative correlation (R= -0.77) between seat belt compliance and road crash fatality rates (Figure 3.2) (Abbas, Hefny & Abu-Zidan, 2011). It has been reported that 50-80% of all road fatalities could be

prevented by proper use of seat belts (FIA Foundation for the Automobile and Society, 2009).

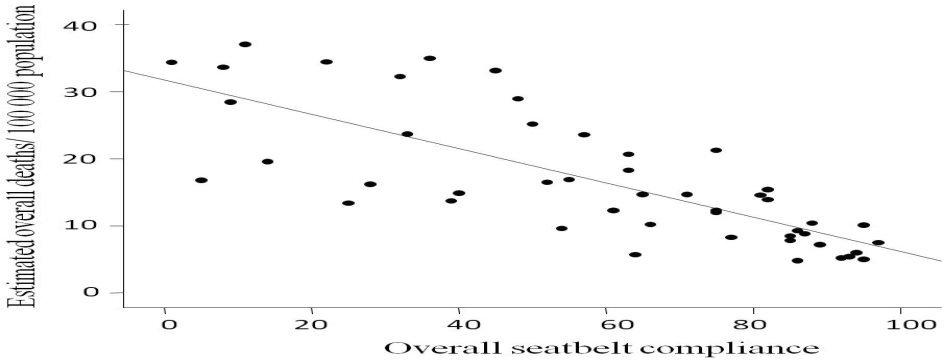

Figure 3.2 Linear Regression between seat belt compliance and road traffic death rates in 46 high income countries (Abbas, Hefny & Abu-Zidan, 2011)

Australia enjoys relatively high overall rates of seat belt use (95-99%) and remains one of the leading countries globally in this regard. However, more than 25% of vehicle occupants killed in road crashes in Australia were reportedly not wearing a seat belt (ATC, 2008). It is estimated that if seat belt wearing rates increased to 100%, the overall cost of road crashes could be reduced by approximately $279 million. (Department of Transport and Regional Services, 2005).

In WA, approximately one third (29%) of police reported motor vehicle occupant fatalities were not wearing a seat belt, comprising 31% of male and 22% of female fatalities (Marchant et al., 2008). Figure 3.3 shows the number and percentage of fatal crashes where seat belts were not worn in WA between 2001 and 2006.

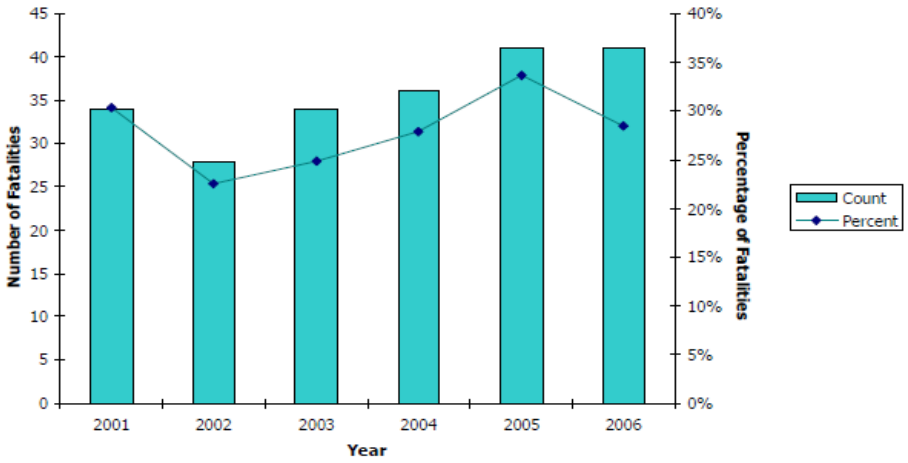

Figure 3.3 Motor vehicle occupant fatalities where seat belts were not worn; by year, Western Australia 2001-2006 (Marchant et al., 2008).

Evidence suggests that seat belt usage rates are lower among motor vehicle occupants in rural or remote areas, than in metropolitan areas of Australia (ATC, 2008). An observational survey in WA found that across all occupant positions and ages, the prevalence of seat belt or restraint use in rural and remote regions varied widely, ranging from 72 to 97%, with non-use being more prevalent in the most remote towns (Roberts, Taylor, & Sidebottom, 2006). In contrast, the prevalence of seat belt or restraint use in metropolitan Perth was 98%. Similarly, Marchant et al. (2008) reported that the proportion of motor vehicle occupants killed or hospitalised due to a crash in WA, who were not wearing a seat belt, increased with the ARIA remoteness index. In very remote areas, 38% of vehicle occupants who were killed or hospitalised were not wearing a seat belt, compared to 18% in remote areas and 4% in highly accessible areas (Marchant, et al., 2008).

Reasons for lower levels of restraint use in rural or remote areas may include higher proportions of Indigenous people (who are less likely to use seat belts) and the perceived lower likelihood of detection by police for failure to wear a seat belt (Oxley et al., 2009).

3.2.3 Alcohol

Drinking and driving increases both the risk of a crash and the likelihood of death or serious injury in the event of a crash (Peden et al., 2004). Alcohol consumption adversely affects judgment, reaction time and vision as well as use of seat belts/ helmets and choice of driving speed (WHO, 2007). Even low Blood Alcohol Concentrations (BAC) can impair judgment and increase crash risk. A BAC of 0.04

g/dl significantly increases the likelihood of involvement in a crash (Moskowitz & Fiorentino, 2000). Laws enforcing low BAC levels, random breath tests and sobriety checkpoints have resulted in a 20% decrease in alcohol related crashes throughout the world (WHO, 2009).

In Australia, alcohol is the single biggest contributor to serious crashes, accounting for 30% of fatal and 9% of serious injury crashes (ATC, 2011). In Australia, the BAC limit for the general population is 0.05g/dl and for young or novice drivers is 0.0 (WHO, 2009). In WA, 26% of fatal crashes involved a driver/rider with a BAC of 0.05 g/100mL or above (Marchant et al., 2008). In addition, 71% of all road users killed or hospitalised in an alcohol-related crash in WA were male (Marchant et al., 2008).

The burden of road crash related injury associated with drink driving is disproportionately high in rural areas of Australia (Havard, Shakeshaft, Conigrave, & Sanson-Fisher, 2011). In 2008, 54% of alcohol-related road fatalities occurred on country roads (Miller, Coomber, Zinkiewicz, & Toumbourou, 2010). In WA in 2006, 48% of alcohol-related road fatalities and hospitalisations occurred in highly accessible areas, 8% in moderately accessible areas and 15% in remote and very remote areas (Marchant et al., 2008). It is clear that remote and very remote areas were over-represented in alcohol-related crashes as the population of these areas is very low.

Evidence suggests that alcohol may also be an important risk factor for fatal pedestrian crashes in rural WA. Among pedestrians killed in 2006 in WA, 14 were killed in the metropolitan area and seven in rural areas. Five out of seven pedestrians killed in rural areas had a BAC of 0.05 g/100mL or above and 4 had a BAC over 0.15 g/100mL. In contrast, only four of the 14 pedestrians killed in the metropolitan area had a BAC of 0.05 g/100mL or greater (Marchant et al., 2008).

There are several reasons why serious injury drink driving-related crashes are over-represented in rural and remote areas. Crashes involving drink driving are often characterised by high speed and involve single vehicles running off the road (WHO, 2007). These crashes are associated with higher severity. In addition, individuals who live in rural and remote areas of Australia have been found to have a greater incidence of high alcohol consumption than those who live in metropolitan areas (Parliament of Victoria Road Safety Committee, 2005). There are also limited

transportation options other than driving and a perceived lower likelihood of being detected drink driving by police than in metropolitan areas.

3.2.4 Fatigue

It has been well established that driving while fatigued is an important contributory factor for fatal and serious injury crashes (Armstrong, Smith, Steinhardt, & Haworth, 2008). There is a substantial body of evidence to show that fatigue adversely affect tasks requiring alertness such as driving (Moskowitz & Fiorentino, 2000). In addition, it has been recognised that fatigue can have comparable impairments on driving capability to alcohol. Consistent with dips in alertness associated with the human circadian rhythm, fatigue-related road crash incidents have been found to peak between 2:00am and 6:00am and 2:00 pm and 4:00 pm (Obst, Armstrong, Smith & Banks, 2011). Evidence also suggests that younger drivers are at higher risk of fatigue-related crashes at night, than other drivers (Obst et al., 2011).

In Australia, fatigue has been identified as an important road safety issue. Fatigue-related crashes are often high severity crashes, with run-off road crashes being the most common. When drivers are fatigued or asleep, they often cannot employ crash avoidance manoeuvres prior to impact, resulting in high speed, high severity crashes (Diamantopoulou, Hoareau, Oxley, & Cameron, 2003). It is difficult however, to determine the proportion of crashes that can be attributed to fatigue. For example, Obst et al. (2011) stated that fatigue could be identified as the primary causal factor in nearly 6% of all road crashes in Australia and 15% of all fatal road crashes. In WA between 2005 and 2007 however, it was estimated that driver fatigue played a role in 20-30% of all road crash deaths and serious injuries (ATC, 2011).

Several reports have identified driver fatigue as a particular safety issue for rural/ remote areas of Australia. This may be due to the high speed limits, long, straight, monotonous stretches of road with little scenery, long distances between towns and long distances travelled in these areas (Centre for Accident Research and Road Safety Queensland (CARRSQ), 2005). According to Ryan, Cercarelli and Mullan (1998), 19% of rural/remote drivers in northern WA reported falling asleep at the wheel at least once. It has been estimated that fatigue is the primary contributing factor in 30% of fatal crashes on rural roads throughout Australia and many contribute to as many as 40-50% of fatal single vehicle semi-trailer crashes (CARRSQ, 2005). In Queensland, the relative risk of dying as a result of a fatigue

related crash was 13.5 times higher in rural than metropolitan areas (CARRSQ, 2005). There is a gap in the evidence surrounding the role of fatigue in crashes in WA specifically.

3.3 Road user type

According to the global report on road safety by the World Health Organization (2009), almost 50% of road deaths worldwide are recorded amongst vulnerable road users. Vulnerable road users include pedestrians, cyclists, drivers of two wheeled motorised vehicles and their passengers. This group of road users does not have a protective shield around them and hence, are at a higher risk of road crash injury/fatality than other road users.

In WA, an increase in the number of fatalities for all road user types was seen in 2006 except for bicyclists (-21 per cent), compared to the previous five year average (Meuleners, 2007). Table 3.1 compares the fatalities among different road user group in the year 2006 with the previous five years.

Table 3.1 Fatalities by road user group and year, Western Australia, 2001-2006

Age Group	2001	2002	2003	2004	2005	5 year average	2006	2006 Percentage change from 5 year average
Driver	71	80	84	85	88	81.6	95	16.4
Passenger	41	47	53	44	36	45.6	50	9.6
Motorcyclist	28	24	23	22	20	23.4	31	32.4
Pedestrian	20	22	18	25	14	19.8	21	6.1
Bicyclist*	5	6	1	3	4	3.8	3	-21.1

(Source: Meuleners, 2007)

The number of hospitalisations for all road user types decreased in 2006 compared to the previous 5 year average, except for motorcyclists (14% increase) and passengers (2% increase).

Table 3.2 Hospitalisations by road user group and year, Western Australia, 2001-2006 (Meuleners, 2007)

Age Group	2001	2002	2003	2004	2005	5 year average	2006	2006 Percentage change from 5 year average
Driver	963	1543	1554	1723	1604	1477.4	1435	-2.9
Passenger	513	725	687	795	790	702	713	1.6
Motorcyclist	219	294	295	342	321	294.2	335	13.9
Pedestrian	160	195	218	207	248	205.6	180	-12.5
Bicyclist*	77	121	121	115	119	110.6	83	-24.9

3.3.1 Pedestrians

In Australia and globally, pedestrian crashes are more common in metropolitan areas, with the majority occurring in 50 or 60 km/hour speed zones (Devlin, Hoareau, Logan, Corben & Oxley, 2010). This is due to higher levels of pedestrian and vehicle activities in metropolitan areas (Zegeer & Bushel, 2011). In WA, there were a total of 104 pedestrian deaths and over 950 serious injuries between 2004 and 2008, representing nearly 10% of all road deaths and approximately 9% of all serious injuries (Oxley, 2010). Child pedestrian crashes usually take place in local streets, near home and while the child is unattended, often on the way to or from school and especially while playing after school. Pedestrian crashes involving older adults occur in built-up areas, close to home and shops, usually on a regular shopping trip, and in complex environments such as strip shopping centres, intersections and two-way roads characterised by heavy and fast traffic.

Although fewer pedestrian crashes occur in rural and remote areas, it has been found that rural and remote crashes are 2.3 times more likely to result in pedestrian death (Mueller, Rivara, & Bergman, 1988). Reasons for this include higher speed limits , fewer separate facilities for pedestrians and long distances from emergency care facilities in rural and remote areas (Mueller et al., 1988). In addition, it has been suggested that many pedestrians who are fatally injured in a crash in rural WA are under the influence of alcohol, which impairs judgement and slows reflexes (Oxley, 2010).

3.3.2 Motorcyclists

Motorcyclists are considered to be vulnerable road users because of their relative lack of protection against impacts with other vehicles, the ground and roadside objects. Therefore, rider injuries are often more severe than those of other road users. The inherent instability of motorcycles also makes them more susceptible to crashing in comparison with other vehicles. Motorcyclists' low conspicuousness (ability to be seen by other road users), small numbers and behavioural factors such as high speeds and unexpected locations (e.g. driving between lanes) also contribute to their high-risk of involvement in a road crash (Blackman, Steinhardt, & Veitch, 2009)

Motorcyclists in Australia are approximately thirty times more likely to be killed in a crash than car occupants (Blackman, Steinhardt, & Veitch, 2009). Even though motorcyclists comprised a small percentage of the WA vehicle fleet (5.4%), they accounted for 15% of all road deaths during 2008 (ORS, 2011a). Motorcycling activity has grown rapidly throughout Australia and motorcycle registrations have increased by 56% between 2005 and 2010 (ATC, 2011). This is expected to increase the number of motorcycle crashes in WA in the coming years (ORS, 2011a).

Single vehicle crashes comprise a significant proportion of motorcycle crash deaths (42%) (ATC, 2011) and a significant proportion of fatal motorcycle crashes take place on rural and remote roads (34%) (ORS, 2011a).

3.3.3 Bicyclists

Worldwide, the majority of bicycle kilometres travelled are undertaken in metropolitan areas, over relatively short distances. Even though cycling rates are relatively low in Australia, in the six year period between 2003 and 2008, fatal cyclist crashes represented 2.3% of all road deaths in Australia (Garrard, Greaves & Ellison 2010).

In WA, over the ten years to 2009, a total of 34 bicyclists were killed and 1,060 were seriously injured (Edwards, 2011). In the metropolitan area of WA between 2000 and 2009, there was a decreasing trend in the number of bicyclist fatalities. Over the same period, the number of bicyclist serious injuries increased by an average of 5% per annum (ORS, n.d.). Between 2000 and 2009, 13 bicyclists were killed in regional and remote areas of WA, with a peak of four fatalities in 2007. During the same period, the number of bicyclists who were seriously injured decreased by an average of five per year (Edwards, 2011). According to the Australian Transport Safety

Bureau (ATSB) (2006) there was no real variation between rural and urban areas in cycling related crashes in Australia during the four year period from 2000-2004.

3.4 Road characteristics

3.4.1 Road alignment

The horizontal and vertical alignments of the road are two important aspects of road design that can influence crash risk. Road alignment influences speed, variations in speed, friction and driver expectations of the road ahead. It has been reported that crash risk increases as the curvature of a road and number of unanticipated curves increases (Elvik & Hoye, 2004). Across Australia and New Zealand, crashes on rural and remote roads more commonly in rural and remote areas. In WA, the majority of crashes occur on straight roads, as straight roads are more common in the road network (Meuleners, 2007). Little is known about the risk of crashes by road alignment in metropolitan, rural and remote WA though Meuleners (2007) did note that single vehicle crashes in 2008 across the metropolitan, regional and remote areas of WA were significantly more likely to occur on curves for the metropolitan area only. However research from Norway found that over 50% of rural crashes occurred on roads with high curvature (Elvik & Hoye, 2004). An analysis of rural crashes in the United Kingdom also suggested that the risk of single vehicle crashes increased with the density of sharp bends (34% increase in crash frequency per additional sharp bend per kilometre) (Taylor, Baruya, & Kennedy, 2002).

3.4.2 Road gradient

Road gradient, or slope of the road is an important road safety factor. Steep uphill slopes may restrict the visibility of the driver and steep downhill slopes may lead to excessive speeds, improper use of brakes and loss of control of the vehicle, particularly for heavy vehicles (Elvik & Hoye, 2004). In Australia, the severity ratio of crashes (fatal crashes versus other) was slightly higher for hilly roads, compared with flat roads for both Local Government and State controlled roads (Turner, Pyta, Wooley & Zhang, 2010). In WA, the majority of all crashes occur on level roads (Meuleners, 2007). However, little is known about differences in the risk of crashes on metropolitan, rural and remote roads in WA.

3.4.3 Road surface

In Australia and in WA overall, the majority of fatal crashes occur on sealed local and State roads (Meuleners, Hendrie, & Lee, 2011; Meuleners, 2007). However, the

vast majority of crashes on unsealed roads occur in regional and remote areas. Crashes in rural and remote areas are more likely to occur on unsealed surfaces (13.8%), compared to metropolitan areas (0.9%) (Legge, Kirov, & Cercarelli, 2001). In addition, unsealed shoulders of sealed roads pose a major hazard to drivers (Baldock, Kloeden & McLean, 2008). When the wheel/wheels of a vehicle come into contact with the unsealed gravel or dirt shoulder, drivers often make a sharp overcorrection, which may result in the vehicle leaving the roadway or colliding with another vehicle (Baldock et al., 2008). Sealed shoulders provide drivers with manoeuvring space and the opportunity to recover safely if the vehicle leaves the lane it is travelling in.

The majority of sealed roads with unsealed shoulders in WA are also in rural and remote areas. Sealing of road shoulders is one of the most common engineering road treatments on rural roads in Australia. One case-control study demonstrated a 43% reduction in casualty crashes following shoulder sealing on Victorian highways in Australia. A recent WA-based study also confirmed that treatment of sealed shoulders was a highly effective method for reducing all-severity crashes, casualty crashes and the cost of crashes at sites on Albany Highway, treated under the State Black Spot Program (Meuleners et al., 2011).

Compared to other OECD countries, Australia has higher speed limits across much of the road system due to its vast regional road network. The majority of regional roads in Australia are single-carriageways with high default speed limits (100 km/hour in most jurisdictions) (ATC, 2011). In rural South Australia, fatal and serious injury crashes were found to be over-represented on roads with speed limits of 80 km/hour or higher (Mackenzie, 2008). In addition, the majority of crashes occurred on roads with speed limits of 110 km/hour and these had the largest proportion of high injury severity outcomes (Mackenzie, 2008). A Queensland-based study also reported that the proportion of crashes in higher speed zones gradually increased as the ARIA remoteness indicator increased (Steinhardt, Sheehan & Siskind, 2009).

3.5 Crash and vehicle characteristics

3.5.1 Multi-vehicle crashes

Multi-vehicle collisions are also an important source of road trauma in metropolitan and rural areas and include collisions at intersections, head-on impacts and rear-end

collisions. Multi-vehicle crashes are often more severe in rural than metropolitan areas due to higher travelling speeds. In WA in 2006, 56% of multi-vehicle fatal crashes occurred in the metropolitan area. In addition, 66% of metropolitan hospitalisation crashes were multi-vehicle, compared to only 30% of rural hospitalisation crashes (Marchant et al., 2008)

3.5.2 Single vehicle crashes

Single-vehicle crashes are a road safety priority in WA due to their large contribution to death and injury on rural roads. In 2008, 56% of fatal crashes in WA occurred on rural roads, with 87% of these fatalities being single-vehicle crashes (Meuleners et al., 2011). Single vehicle crashes have been found to commonly occur at high speeds, on curved and unsealed roads and often have more severe outcomes than multi-vehicle crashes (Ryan et al., 1998).

In WA in 2006, there was a 63% increase in hit object crashes in metropolitan areas, an 18% increase in hit object and 29% increase in non-collision crashes in rural areas, compared to the previous five year average.

3.5.3 Vehicle type

In WA between 2001 and 2006, sedans/hatchbacks were the most common vehicle type involved in fatal and hospitalisation crashes. In rural and remote areas, there is a high dependency on self-owned vehicles, due to lack of alternative transport options. Rural and remote environments constitute a mix of vehicle types including cars, buses, heavy trucks, agricultural vehicles, mopeds and bicycles and this diverse mix increases the likelihood of a crash in these road environments. Even so, Tziotis et al. (2006) noted that rigid and articulated trucks had a relatively high crash rate on rural and remote roads compared with metropolitan roads for crashes occurring on Australian and New Zealand roads, 1999-2003.

3.6 Limitations

A key concern of this literature review that has implications for its findings, is the major inconsistencies in defining “rural” and “remote” areas in the literature. In addition, there were inconsistencies in defining crash severity levels. Despite the definition of a road fatality being relatively clear, the definition of a serious injury varies widely between jurisdictions. These definitional ambiguities mean that findings and research studies needed to be carefully examined to determine their definitional base.

3.7 Summary and conclusion

This literature review summarised the existing evidence on factors associated with serious injury crashes in different geographic locations (metropolitan, rural and remote areas). Factors reviewed include demographic, behavioural, road user, road and crash/ vehicle characteristics. Main findings include:

Demographic factors

- Fatal and injury crash rates may be lower for metropolitan versus rural novice drivers up to two years post licensure.
- Males are more commonly involved in rural and remote area fatal and hospitalisation crashes than females.

Driver behavioural factors

- In Western Australia in 2011 speed compliance was noted to be higher on rural roads compared with metropolitan roads.
- Speeding is estimated to be a contributing factor in 24% of all police attended fatal crashes state-wide, with the proportion being highest for fatal crashes in the remote area and lowest in the metropolitan area.
- Seat belt usage rates are lower among motor vehicle occupants in rural or remote areas (72-97%), than in metropolitan areas of WA (98%).
- The proportion of motor vehicle occupants in WA killed or hospitalised due to a crash, not wearing a seat belt, increases with the ARIA remoteness index.
- The burden of road crash related injury associated with drink driving is disproportionately high in rural areas of Australia.
- 19% of rural/ remote drivers in northern WA report falling asleep at the wheel at least once.
- It has been estimated that fatigue is the primary contributing factor in 30% of fatal crashes on rural roads throughout Australia.

Road user type

- In Western Australia the majority of pedestrian crashes occur in metropolitan areas but rural and remote pedestrian crashes are more likely to result in death.
- Alcohol consumption by pedestrians may be an important risk factor in fatal pedestrian crashes in rural and remote areas.

- A significant proportion of fatal motorcycle crashes take place on rural and remote roads (34%).
- Little is known about the risk factors for bicycle crashes in rural and remote areas.

Road characteristics

- In Western Australia, the majority of crashes state-wide occur on straight roads. However, international evidence suggests that the risk of single vehicle crashes increases with the density of sharp bends in rural areas.
- In WA, the majority of all crashes occur on level roads. Little is known about differences in the risk of crashes on metropolitan, rural and remote roads in WA.
- The majority of fatal crashes occur on sealed roads in Australia. However, crashes in rural and remote areas are more likely to occur on unsealed surfaces compared to metropolitan areas.
- The majority of sealed roads with unsealed shoulders in WA are in rural and remote areas. Treatment of sealed shoulders is a highly effective method for reducing all-severity crashes, casualty crashes and the cost of crashes.
- The proportion of crashes in higher speed zones gradually increases as the ARIA remoteness indicator increases.

Crash and vehicle characteristics

- The majority (87%) of fatalities on rural and remote roads are due to single-vehicle crashes. Single vehicle crashes have been found to commonly occur at high speeds and on curved and unsealed roads and often have more severe outcomes than multi-vehicle crashes.
- Rural and remote environments constitute a mix of vehicle types including cars, buses, heavy trucks, agricultural vehicles, mopeds and bicycles and this diverse mix increases the likelihood of a crash in these road environments, with some evidence of a higher risk of heavy vehicles crashing on non-metropolitan roads.

Conclusion

Fatal and serious injury crashes are significant issues across metropolitan, rural and remote WA with a higher risk of death and serious injury when crashes occur in non-urban areas. This review has identified several risk factors for crashes in these geographical regions and how they differ between regions. Existing evidence

however, comes from several different sources internationally and nationally, using a wide variety of definitions for geographical regions and crash severity. The WA road environment is unique, covering vast distances with extremely varied road conditions. Therefore, to better understand the different risk factors for serious injury crashes in metropolitan, rural and remote areas of WA and to develop relevant counter measures that addressing safer roads, safer speeds, safer vehicles and safer road users it is essential to undertake comprehensive analyses using WA data.

4. ANALYSIS OF WESTERN AUSTRALIAN CRASH DATA 2005-2009

4.1 Crash severity and location of crashes

A total of 196,276 crashes were recorded by WA Police during the period 2005-2009. Approximately 82% of crashes occurred in the metropolitan Perth area, 12% in the regional area, and 6% in the remote area of WA (Table 4.1). Crashes with the highest injury severity of either the death or hospitalisation of an involved road user - defined as 'serious injuries' and the focus of this project - totalled 11,874 and accounted for 6.1% of all crashes recorded during the study period. Minor injury crashes requiring medical treatment only constituted a further 13.8%. The majority (80.1%) of crashes across the State resulted in no personal injury to an involved road user but minor to major property damage only.

Table 4.1 Severity of crashes; by location, Western Australia, 2005-2009

Crash Severity	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Fatal	392	0.2	285	1.2	235	2.1	912	0.5
Hospitalisation	7660	4.7	1996	8.4	1306	11.9	10962	5.6
All Serious	*8052*	*4.9*	*2281*	*9.6*	*1541*	*14.0*	*11874*	*6.1*
Row %		*67.8*		*19.2*		*13.0*		*100.0*
Medical	22606	14.0	3094	13.1	1331	12.1	27031	13.8
PDO Major	95285	59.0	13652	57.8	6340	57.7	115277	58.7
PDO Minor	35682	22.1	4609	19.5	1778	16.2	42069	21.4
All crashes	161625	100.0	23636	100.0	10990	100.0	196251	100.0

n=26 missing Location. PDO: Property Damage Only. Chi Square: X^2=27003.55 df=8; $p \leq .001$.

The majority of serious injury crashes were noted to have occurred in the metropolitan area (67.8%) versus the regional (19.2%) and remote areas (13%), with serious injury crashes accounting for a significantly higher proportion of crashes in the regional (9.6%) and remote (14%) areas compared with the metropolitan area (4.9%).

Calculation of the unadjusted odds of a crash resulting in (i) any injury to an involved road user *versus* no-injury, and (ii) serious injury to an involved road user *versus* no serious injury, showed a significant increased likelihood of both outcomes with increasing distance and remoteness from the metropolitan area. As shown in Table 4.2, a crash in the regional and remote area was respectively 25% and 50%

more likely to result in an injury (any level) to an involved road user, and two to three times more likely to result in a serious injury (death or hospitalisation) of an involved road user.

Table 4.2 Unadjusted odds of an injury crash (any level) and serious injury crash; by location of crash, Western Australia, 2005-2009

	Odds Ratio	95% CI	P-value
Crash resulting in any level of injury			
*Metropolitan^*	1.0		
Regional	1.25	1.21-1.29	<0.001
Remote	1.51	1.44-1.58	<0.001
Crash resulting in a serious injury			
*Metropolitan^*	1.0		
Regional	2.03	1.94-2.13	<0.001
Remote	3.10	2.94-3.29	<0.001

^reference group

Further analysis showed that when a serious injury crash did occur, it was significantly more likely to result in the death of a road user in the remote (OR=4.59, 95% CI 4.08-5.10) and regional areas (OR=3.05 95% CI 2.74-3.41) compared with the metropolitan area.

4.2 Serious injury crash analysis

A detailed analysis of the sub-group of serious injury only crashes across the metropolitan, regional and remote areas of Western Australia is presented in the following sections. The analysis was undertaken with respect to selected crash, road, road user and vehicle characteristics.

4.2.1 Selected crash characteristics

Descriptive findings for the nature of the crash; road user movement; time of day; lighting; day of week, and weather are considered for each location in the following sections.

4.2.1.1 Nature

Nearly 40% of metropolitan area serious injury crashes related to right angle or right turn thru scenarios. The next major category of crashes in this location was hit object

single vehicle crashes (20.6%). In contrast, hit object crashes were the predominant crash type for the regional (45%) and remote areas (37.6%). A further two-thirds of serious injury crashes in the remote area were designated as non-collisions or roll-overs, which was significantly greater than that for the regional (14.4%) and metropolitan areas (5.9%). A statistically significant association was computed between the nature of the crash and location of occurrence.

Table 4.3 Crash nature of serious injury crashes; by location, Western Australia, 2005-2009

Nature of Crash	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Rear End	1256	16.0	150	6.7	41	2.7	1147	12.5
Head On	272	3.5	139	6.2	56	3.7	467	4.0
Sideswipe Same Direction	416	5.3	65	2.9	27	1.8	508	4.4
Right Angle	1899	24.2	275	12.3	95	6.3	2269	19.6
Right Turn Thru	1154	14.7	109	4.9	33	2.2	1296	11.2
Hit Pedestrian	759	9.7	122	5.5	100	6.7	981	8.5
Hit Animal	25	0.3	39	1.8	44	2.9	108	0.9
Hit Object	1616	20.6	1007	45.2	564	37.6	3187	27.5
Non-Collision	463	5.9	321	14.4	540	36.0	1324	11.4
Total	7860	100.0	2227	19.2	1500	12.9	11587	100

n=287 missing Nature information. Chi Square: X^2=2506.34 df=16; $p \leq .001$

Hit object crashes across metropolitan, regional and remote areas

Analysis of hit object serious injury crashes for all three locations revealed a statistically significant association between location of crash and the *primary* object[1] of collision. Table 4.4 shows the distribution of seven specific objects, which accounted for 86.1%, 81.5% and 82.2% of primary objects hit in metropolitan, regional and rural serious injury crashes respectively. Roadside kerbs (22.3%) followed by Trees/Shrubs (19.0%) were the most common objects hit in metropolitan area crashes. In contrast, Trees/Shrubs accounted for 46.7% and 34.3% respectively of objects hit in regional and remote crashes. Embankments accounted for a further 22.4% of objects hit in remote area crashes, nearly twice the proportion of regional crashes and six times the proportion of metropolitan crashes.

[1] Primary object of collision may not necessarily be the main cause of injury if a subsequent object was collided with. This is especially relevant when a kerb is noted as the primary object.

Table 4.4 Selected primary object types for hit object serious injury crashes; by location, Western Australia, 2005-2009

Object Type	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Electricity Pole	226	14.1	33	3.2	19	3.4	277	8.8
Other Pole, Post, Sign	115	7.2	78	7.8	60	10.8	253	8.0
Guard Rail	30	1.9	7	0.7	1	0.2	38	1.2
Tree/Shrub	306	19.0	467	46.7	191	34.3	964	30.5
Traffic Island	290	18.0	46	4.6	14	2.5	350	11.1
Kerb (cause)	359	22.3	60	6.0	48	8.6	467	14.8
Embankment	59	3.7	125	12.5	125	22.4	309	9.8
All other primary objects	223	13.9	185	18.5	99	17.8	507	16.0
Total	1608	100.0	1091	100.0	627	100.0	3165	100.0

n=22 missing primary Object type information; Chi Square: X^2=726.98 df=14; $p \leq .001$.

4.2.1.2 Road use movement

Analysis of serious injury crashes by road use movement patterns revealed a statistically significant association with location of crash (Table 4.5). Loss of control, single vehicle crashes - off straight/on straight and off curve/on curve - accounted for the majority of regional (56.9%) and remote area (70.7%) crashes. In contrast, road use movements associated with a serious injury crash in the metropolitan area were more diverse but mostly involved conflict between vehicles. Nearly one in five serious injury crashes related to each of the following road use movements: crashes at intersections; vehicles travelling from opposing directions; vehicles travelling in the same direction, and loss of control, single vehicle crashes- off straight/on straight.

Table 4.5 Categories of road user movements for serious injury crashes; by location, Western Australia, 2005-2009

RUM class	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Pedestrian	749	9.3	120	5.3	99	6.4	968	8.2
Intersection (adjacent approaches)	1658	20.6	235	10.3	76	4.9	1969	16.6
Vehicles from opposing directions	1445	17.9	236	10.3	87	5.6	1768	14.9
Vehicles from same direction	1473	18.3	184	8.1	41	2.7	1698	14.3
Manoeuvring	325	4.0	52	2.3	28	1.8	405	3.4
Overtaking	110	1.4	67	2.9	32	2.1	209	1.8
On path	188	2.3	69	3.0	74	4.8	331	2.8
Off/on straight	1376	17.1	715	31.3	695	45.1	2786	23.5
Off/on curve	672	8.3	585	25.6	395	25.6	1652	13.9
Passengers and Misc.	56	0.7	18	0.8	14	0.9	88	0.7
Total	8052	100.0	2281	100.0	1541	100.0	11874	100.0

Chi Square: X^2=1918.32 df=18; $p \leq .001$. RUM=Road User Movement

4.2.1.3 Time of day

Time of day of serious injury crashes by location is presented in Table 4.6. The highest proportion of serious injury crashes occurred in the 12:00 to 17:59 period. The proportion of crashes in each location during this time was similar: metropolitan 36.6%; regional 39.5%; remote 35.4%. A statistically significant association was computed however, between time of day and location, with a higher than expected number of crashes occurring in the regional and remote areas and lower than expected number of crashes occurring in the metropolitan areas during the 00:00 to 05:59 period.

Table 4.6 Time of day of serious injury crashes; by location, Western Australia, 2005-2009

Time of day	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
00.00-05:59	828	10.4	285	12.6	210	13.8	1323	11.3
06.00-11:59	2104	26.4	541	24.0	369	24.3	3014	25.7
12:00-17:59	2912	36.6	893	39.5	539	35.4	4344	37.0
18:00-24:00	2116	26.6	539	23.9	403	26.5	3058	26.0
Total	7960	100.0	2258	100.0	1521	100.0	11739	100.0

n=135 missing Time of Day. Chi Square: X^2=33.60 df=6; $p \leq .001$

4.2.1.4 Lighting

Information on the lighting conditions at the location of crash is presented in Table 4.7. Across all locations, the majority of crashes occurred during daylight. There were however, significant variations across locations in the lighting conditions for the remaining serious injury crashes. Around one in five and one in four serious injury crashes respectively in regional and remote locations occurred when it was dark and without street lighting, compared with just 3.5% of crashes in the metropolitan area. Further to this, nearly 30% of crashes in the metropolitan area occurred when it was dark but the street was lit, compared with around one in ten crashes in the regional and remote areas.

Table 4.7 Lighting conditions for serious injury crashes; by location, Western Australia, 2005-2009

Lighting Conditions	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Daylight	4938	62.6	1436	64.1	884	58.5	7258	62.4
Dawn or Dusk	338	4.3	101	4.5	98	6.5	537	4.6
Dark-lights on	2274	28.8	231	10.3	166	11.0	2671	22.9
Dark-lights off	60	0.8	18	0.8	10	0.7	88	0.8
Dark-no lights	277	3.5	455	20.3	354	23.4	1086	9.3
Total	7887	100.0	2241	100.0	354	100	11640	100.0

n=234 missing Lighting Condition. Chi Square: X^2=1284.60 df=8; $p \leq .001$

4.2.1.5 Day of week

Across the days of the week and all locations, the highest proportion of serious injury crashes occurred on Friday (17%) followed by Saturday (16.4%). A statistically

significant association was computed between location and day of week of crash. A *higher* than expected number of crashes occurred in the regional and remote areas on a Saturday and Sunday; while a *higher* than expected number of crashes occurred in the metropolitan area on a Tuesday and Wednesday and to a lesser extent, Thursday.

Table 4.8 Day of week of serious injury crashes; by location, Western Australia, 2005-2009

Day of Week	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Monday	1005	12.5	281	13.2	183	11.9	1469	12.4
Tuesday	1107	13.7	264	11.6	183	11.9	1544	13.1
Wednesday	1117	13.9	275	12.1	180	11.7	1572	13.2
Thursday	1159	14.4	293	12.8	195	12.7	1647	13.9
Friday	1415	17.6	363	15.9	243	15.8	2021	17.0
Saturday	1244	15.4	401	17.6	303	19.7	1948	16.4
Sunday	1005	12.5	404	17.7	254	16.5	1663	14.0
Total	8052	100.0	2281	100.0	1541	100.0	11874	100.0

Chi Square: X^2=84.78 df=12; $p \leq .001$

4.2.2 Road characteristics

The road characteristics considered in this section include: road ownership; posted speed zone; road surface; road alignment; road gradient, and the condition of the road at the time of the crash.

4.2.2.1 Speed zone

Posted speed limit was found to be significantly associated with the location of the serious injury crash. Around six in ten serious injury crashes in the metropolitan area occurred on roads with posted speed limits of 60km/hour or less, compared with three in ten in the regional area and one in five in the remote area. In contrast, the majority of serious injury crashes in regional (46.5%) and remote areas (62.1%) of Western Australia occurred on roads with the maximum posted speed limit (110km/hour).

Table 4.9 Posted speed zone of serious injury crashes; by location, Western Australia, 2005-2009

Speed Zone	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
40km/hour or less	59	1.0	8	0.4	3	0.3	70	0.8
50km/hour	1470	24.1	281	15.7	166	14.0	1917	21.1
60km/hour	2181	35.7	235	13.1	116	9.8	2532	27.9
70km/hour	1120	18.4	103	5.7	31	2.6	1254	13.8
80km/hour	352	10.7	148	8.2	68	5.7	868	9.6
90km/hour	156	2.6	114	6.4	48	4.0	318	3.5
100km/hour	363	5.9	71	4.0	19	1.6	453	5.0
110km/hour	100	1.6	835	46.5	738	62.1	1673	18.4
Total	6101	100.0	1795	100.0	1189	100.0	9085	100.0

n=2789 missing Speed Zone. Chi Square: X^2=3853.40 df=14; $p \leq .001$

4.2.2.2 Road surface

Across all locations, 95% of serious injury crashes occurred on roads that were sealed as opposed to unsealed. This finding is consistent with a higher level of travel on the predominantly sealed road network in the metropolitan area. Consistent with this, the proportion of serious injury crashes occurring on unsealed roads was substantially higher in the remote area (21.9%) and just slightly higher in regional area (7.7%) of Western Australia. This distribution contributed to the finding of a significant association between road surface and location of crash.

Table 4.10 Road surface of serious injury crashes; by location, Western Australia, 2005-2009

Road Surface	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Sealed	7961	99.5	2096	92.3	1198	78.1	11255	95.3
Unsealed	41	0.5	176	7.7	335	21.9	552	4.7
Total	8002	100.0	2272	100.0	1533	100.0	11807	100.0

n=67 missing Road Surface. Chi Square: X^2=86.51 df=2; $p \leq .001$

4.2.2.3 Road alignment

Across all locations serious injury crashes were more likely to occur on straight sections of the road (76.9%), compared with curved (23.1%). Perhaps consistent with the distribution of straight and curved sections of road across the State road network, a significant association was found between road alignment and location of crash. Crashes on curved sections of road were twice as likely in the regional (35.8%) and remote areas (32.4%) of Western Australia compared with the metropolitan area (17.6%).

Table 4.11 Road alignment of serious injury crashes; by location, Western Australia, 2005-2009

Road Alignment	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Curved	1359	17.6	799	35.8	489	32.4	2647	23.1
Straight	6355	82.4	1432	64.2	1022	67.2	8809	76.9
Total	7714	100.0	2231	100.0	1511	100.0	11456	100.0

n=418 missing Road Alignment. Chi Square: X^2=406.44 df=2; p ≤ .001

4.2.2.4 Road gradient

Just over three-quarters of serious injury crashes across Western Australia occurred on a level grade, with a further 22% occurring on a slope. These proportions did not vary significantly across the metropolitan, regional and remote areas.

Table 4.12 Road grade of serious injury crashes; by location, Western Australia, 2005-2009

Road Grade	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Level	5833	75.4	1625	73.7	1153	76.8	8611	75.3
Crest of Hill	209	2.7	64	2.9	41	2.7	314	2.7
Slope	1692	21.9	516	23.4	308	20.5	2516	22.0
Total	7734	100.0	2205	100.0	1502	100.0	11441	100.0

n=433 missing Road Grade. Chi Square: X^2=4.92 df=4; p=.288

4.2.2.5 Road condition

Across all locations the vast majority of serious injury crashes (85%) occurred during dry conditions, with this proportion being highest in remote Western Australia (92.6%). Serious injury crashes whilst wet were more frequent in the metropolitan

area (16.6%), compared with regional (14.4%) and remote areas (7.4%). The rainfall pattern across these locations is likely to be an important factor in the observed significant relationship between weather and location of crash.

Table 4.13 Condition of road of serious injury crashes; by location, Western Australia, 2005-2009

Road Condition	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Wet	1322	16.6	324	14.4	112	7.4	1758	15.0
Dry	6632	83.4	1928	85.6	1408	92.6	9968	85.0
Total	7954	100.0	2252	100.0	1520	100.0	11726	100.0

n=148 missing Road Condition. Chi Square: X^2=86.51 df=2; p ≤ .001

4.2.2.6 Road ownership

Approximately six in ten serious injury crashes across all locations occurred on roads that are the direct responsibility of Western Australian local government. This proportion was highest for serious injury crashes occurring in metropolitan Perth (66.4%) and similar for crashes occurring in regional (47.7%) and remote (48.6%) Western Australia.

Table 4.14 Road ownership of serious injury crashes; by location, Western Australia, 2005-2009

Road Ownership	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Local Government	5301	66.4	1069	47.7	710	48.6	7080	60.6
State/Federal Government	2687	33.6	1173	52.3	750	51.4	4610	39.4
Total	7988	100.0	2242	100.0	1460	100.0	11690	100.0

n=184 missing Road Ownership. Chi Square: X^2=355.29 df=2; p ≤ .001

Analysis of the ownership of the road by road surface (sealed; unsealed) showed a statistically significant relationship for the regional (X^2=164.76 df=1; p ≤ .001) and remote (X^2=196.84 df=2; p ≤ .001) areas only. A higher than expected number of serious injury crashes occurred on local government owned, unsealed roads in the regional (97.4% of serious injury crashes on unsealed roads) and remote (87.5% of serious injury crashes on unsealed roads) areas.

4.2.3 Road user characteristics

A total of 25,798 road users were recorded by police as being involved in the 11,874 serious crashes occurring during the study period. It must be borne in mind that this number does not for a number of reasons, represent the actual number of crash involved road users. One reason is that during the study period, police were not required to record the involvement of road users who were not the controller of the vehicle and were not injured.

Approximately three quarters of those reported to be involved in a serious injury crash were designated drivers/riders. A further 21% were passengers (including those on motorcycles and bicycles) with the remainder designated as pedestrians. The majority of road users within each group were involved in crashes occurring in the metropolitan area. A significant association was found between road user status and location of crash with a higher than expected number of passengers involved in serious injury crashes occurring in the regional (26.1%) and remote (38.5%) areas, compared with the metropolitan area (16.5%). Also, a higher than expected number of pedestrians were found to be involved in crashes in the metropolitan area (4.7%), compared with regional (3.1%) and remote (3.5%) areas of WA.

Table 4.15 Road users involved in serious injury crashes; by location, Western Australia, 2005-2009

Road User	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Driver/Rider*	14310	78.8	3178	70.8	1834	58.0	19322	74.9
Passenger^	3007	16.5	1170	26.1	1217	38.5	5394	20.9
Pedestrian	837	4.7	136	3.1	109	3.5	1082	4.2
Total	18154	100.0	4484	100.0	3160	100.0	25798	100.0

Chi Square: X^2=883.02 df=4; p ≤ .001; *also includes drivers of tractors, motorised wheelchairs and riders of bicycles; ^includes passengers on motorcycles and bicycles.

4.2.4 Drivers/riders

The injury outcome, age, sex, licensing status, seat belt/helmet use, and Blood Alcohol Concentration Level (BACL) of drivers (car, motorbike and bicyclists) involved in a serious injury crash across the three locations are presented in Tables 4.16 to 4.22.

4.2.4.1 Injury outcome

Injury information was available for 61% (n=11,772) of the n=19,322 drivers/riders recorded to be involved in a serious injury crash. The remaining drivers/riders for whom no injury information was recorded may have either been uninjured or failed to have their injury recorded by police. These drivers/riders were therefore excluded from the analysis of injury outcomes.

Of the drivers/riders with a known injury outcome, the majority (80.1%) required hospitalisation while a further 5.5% were fatally injured. The injury outcomes of drivers/riders were found to vary with the location of crash. Drivers/riders injured in a serious injury crash in the regional (9.6%) and remote (10.5%) areas were approximately three times more likely to be killed compared with those involved in a serious injury crash in the metropolitan area (3.5%).

Table 4.16 Injury outcome* of drivers/riders involved in serious injury crashes; by location, Western Australia, 2005-2009

Injury Outcome	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Death	285	3.5	221	9.6	146	10.5	652	5.5
Medical attention	741	9.2	231	10.0	124	8.9	1096	9.3
Hospitalisation	6580	81.4	1773	77.1	1082	77.7	9435	80.1
Injury not requiring medical attention	475	5.9	74	3.2	40	2.9	589	5.0
Total	8081	100.0	2299	100.0	1392	100.0	11772	100.0

n=7,550 no Injury information. Chi Square: X^2=236.19 df=6; p ≤ .001. *The injury outcome is a person level variable.

4.2.4.2 Age

Police crash records show that n=264 drivers/riders involved in a serious injury crash were aged up to 16 years. Approximately 27% of serious injury crash involved drivers/riders were aged 17-24 years and a further 31% aged 25-39 years. Age of driver/rider and location of crash were significantly related. In the regional area, a higher than expected number of drivers/riders aged 12-16 years, 17-24 years and 60+ years were involved in a crash. In the remote area, a higher than expected number of drivers/riders aged 40-59 years were involved in a crash.

Table 4.17 Age of drivers/riders involved in serious injury crashes; by location, Western Australia, 2005-2009

Age Group	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Up to 11 years	33	0.2	13	0.4	4	0.2	50	0.3
12-16 years	129	1.0	57	1.9	28	1.6	214	1.2
17-24 years	3644	27.2	848	27.8	468	26.6	4960	27.3
25-39 years	4278	32.0	853	28.0	588	33.4	5719	31.4
40-59 years	3772	28.2	861	28.2	252	29.8	5158	28.4
60+ years	1525	11.4	418	13.7	146	8.3	2089	11.5
Total	13381	100.0	3050	100.0	1759	100.0	18190	100.0

n=1132 missing Age. Chi Square: X^2=69.17 df=10; p ≤ .001

4.2.4.3 Sex

Males accounted for approximately two-thirds of all drivers/riders involved in a serious injury crash across all locations, with a significant relationship being observed between driver/rider sex and location of serious injury crash. The proportion of male drivers/riders involved in a serious injury crash was somewhat higher for crashes occurring in the regional area (68.4%) and higher again in the remote area (71.4%), compared with the metropolitan area (65%).

Table 4.18 Sex of drivers/riders involved in serious injury crashes; by location, Western Australia, 2005-2009

Sex	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	N	%	N	%	n	%
Male	9044	65.0	2133	68.4	1285	71.4	12462	66.2
Female	4871	35.0	984	31.6	514	28.6	6369	33.8
Total	13915	100.0	3117	100.0	1799	100.0	18831	100.0

n=491 missing Sex. Chi Square: X^2=37.93.02 df=2; p ≤ .001

4.2.4.4 Licensing status

The frequency distribution of the licensing status of drivers/riders involved in a serious injury crash across the three locations is presented in Table 4.19. This analysis was restricted to drivers/riders of vehicle types requiring a licence to be driven/ridden (e.g., cars, buses, trucks, motorcycles, mopeds and on-road trail bikes). Across all locations, 79.7% of serious injury crash involved drivers/riders held a full licence, with a further 11.1% holding a provisional licence. Licensing status was

found to be significantly associated with the location of the crash. In particular, drivers/riders crashing in the remote area were somewhat more likely to be unlicensed (6.9%) or to be driving on a cancelled (4.9%) or suspended licence (3.9%).

Table 4.19 Licensing status of drivers/riders* involved in serious injury crashes; by location, Western Australia, 2005-2009

Licensing Status	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Full	9673	81.0	2136	77.3	1154	73.4	12963	79.7
Suspended	358	3.0	75	2.7	62	3.9	495	3.0
Learner	212	1.8	71	2.6	40	2.5	323	2.0
Cancelled	149	1.2	49	1.8	77	4.9	275	1.7
Unlicensed	230	1.9	66	2.4	109	6.9	405	2.5
Probationary	1314	11.0	367	13.3	130	8.3	1811	11.1
Total	11936	100.0	2764	100.0	1572	100.0	16272	100.0

n=1940 missing Licensing Status. *Includes drivers and riders of motorised vehicles requiring a licence. Chi Square: X^2=300.47 df=10; $p \leq .001$

Multivariate analysis (see Table 4.20) of the licensing status of serious injury crash involved drivers/riders in each location was undertaken to determine the risk of driving unlicensed associated with sex and age. For this analysis drivers/riders crashing whilst not holding a valid licence (i.e., suspended, cancelled, unlicensed) were considered together as 'unlicensed drivers'.

In each location, males were around 1.5 times to two times more likely than females to be unlicensed at the time of the serious injury crash, with the risk being significantly greater for males crashing in metropolitan Perth area (OR=1.99) compared with regional (OR=1.43) and remote (OR=1.63) WA. Driver/rider age was also found to be significantly related to unlicensed driving, particularly for those aged 17-24 and 25-39 years, compared with those aged 60+ years. However, the computed risks for these age groups must be viewed with caution, though less so for those crashing in remote WA, because of the relatively small number of unlicensed drivers and the broad confidence intervals associated with these respective age levels.

Table 4.20 Driver demographics associated with unlicensed driving for those involved in a serious injury crash in the metropolitan, regional and remote areas of Western Australia; 2005-2009

Location/Variable	OR	95% Confidence Interval	P value
Metropolitan Area			
Sex			
-Female^	1.0		
-Male	1.99	1.66-2.38	.000
Age (years)			
-60+ ^	1.00		
-40-59	4.62	2.23-9.55	.000
-25-39	17.05	8.43-34.47	.000
-17-24	13.93	6.87-28.26	.000
Regional Area			
Sex			
-Female^	1.0		
-Male	1.43	1.05-2.04	.047
Age (years)			
-60+ ^	1.00		
-40-59	14.67	1.99-108.11	.000
-25-39	43.91	6.08-316.91	.000
-17-24	33.89	4.68-245.38	.000
Remote Area			
Sex			
-Female^	1.0		
-Male	1.63	1.16-2.30	.01
Age (years)			
-60+ ^	1.00		
-40-59	2.01	0.83-4.85	ns
-25-39	5.06	2.16-11.83	.000
-17-24	4.93	2.09-11.62	.000

^reference group

4.2.4.5 Blood Alcohol Concentration Level

Blood Alcohol Concentration Level (BACL) information was available for 62.5% of drivers/riders involved in a serious injury crash during the study period. A significant association was found between the presence of alcohol and location of crash (Table 4.21). Drivers/riders involved in a serious injury crash in metropolitan Perth were less likely to record a positive BACL (i.e., greater than zero) (11.2%) compared with drivers/riders involved in a serious injury crash in regional (16.5%) and remote Western Australia (23.4%).

Table 4.21 Presence of alcohol among drivers/riders involved in serious injury crashes; by location, Western Australia, 2005-2009

Presence of alcohol	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Zero BACL	7886	88.8	1706	83.5	875	76.6	10467	86.8
Positive BACL*	992	11.2	338	16.5	267	23.4	1597	13.2
Total	8878	100.0	2044	100.0	1142	100.0	12064	100.0

n=7258 missing BACL; Chi Square: X^2=154.57 df=2; p ≤ .001. *Greater than 0.000gm%

Further analysis of the crash and alcohol data showed that approximately 63.3% of drivers/riders involved in a serious injury crash across WA and testing positive for alcohol, recorded a BACL exceeding 0.08gm%. This proportion was significantly higher for drivers crashing in remote Western Australia (74.6%) and slightly higher for those crashing in regional Western Australia (61.2%), compared with metropolitan Perth (60.9%).

Table 4.22 Positive Blood Alcohol Concentration Level of drivers/riders involved in serious injury crashes; by location, Western Australia, 2005-2009

Level of +ve BAC	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
0.001-0.019gm%	73	7.4	23	6.8	9	3.4	105	6.6
0.020-0.049gm%	160	16.1	52	15.4	29	10.9	241	15.1
0.050-0.079gm%	155	15.6	56	16.6	30	11.2	241	15.1
0.080-0.100gm%	131	13.2	41	12.1	29	10.9	201	12.6
≥0.101gm%	473	47.7	166	49.1	170	63.7	809	50.7
Total	992	100.0	338	100.0	267	100.0	1597	100.0

Chi Square: X^2=24.13 df=8; p ≤ .005

Multivariate analysis of the effect of driver/rider sex, age, and licensing status on driver/rider BACL (zero *versus* positive) was undertaken for serious injury crashes occurring in each location. As shown in Table 4.23, in all locations male drivers/riders were two to three times more likely than their female counterparts to have crashed with a positive BACL. Next, drivers who crashed and did not hold a valid licence were significantly more likely to have crashed with a positive BACL. This ranged from 3.7 times more likely for metropolitan driver/riders to a high of 6.4

times for regional driver/riders. Age of driver/riders was consistently and linearly related to an increased likelihood of crashing with a positive BACL, particularly for those crashing in the metropolitan and regional areas. The increased risk associated with age identified for remote area crashes must be viewed with caution due to the relatively smaller number of positive BACL drivers/riders and the broad confidence intervals associated with the calculated risk.

Table 4.23 Driver demographics and licensing status associated with a positive BACL for drivers/riders involved in a serious injury crash in the metropolitan, regional and remote areas; Western Australia 2005-2009

Location/Variable	OR	95% Confidence Interval	P value
Metropolitan Area			
Sex			
-Female^	1.0		
-Male	2.41	2.02-2.87	.000
Age (years)			
-60+ ^	1.00		
-40-59	2.30	1.46-3.61	.000
-25-39	5.46	3.54-8.41	.000
-17-24	7.64	4.97-11.74	.000
Licence Status			
-Licensed^	1.0		
-Unlicensed	3.7	3.08-4.66	.000
Regional Area			
Sex			
-Female^	1.0		
-Male	2.19	1.60-2.99	.000
Age (years)			
-60+ ^	1.00		
-40-59	2.43	1.20-4.911	.013
-25-39	6.65	3.39-13.02	.000
-17-24	7.23	3.71-14.10	.000
Licence Status			
-Licensed^	1.0		
-Unlicensed	6.47	4.25-9.85	.000
Rural Area			
Sex			
-Female^	1.0		
-Male	3.00	1.97-4.58	.000
Age (years)			
-60+ ^	1.00		
-40-59	13.18	1.77-98.19	.012
-25-39	30.92	4.19-228.06	.001
-17-24	33.38	4.59-250.67	.001
Licence Status			
-Licensed^	1.0		
-Unlicensed	5.35	3.61-7.92	.000

^ reference group

4.2.4.6 Use of protection

Seat belt/helmet wearing was analysed for drivers and riders of known vehicle types, (including bicycles) who are required to use protection. Overall, 94.3% of drivers/riders involved in a serious injury crash reportedly used a seat belt/helmet. A significant relationship was computed between use of protection and the location of crash. Non-use was lowest among drivers/riders crashing in metropolitan Perth (4%) and higher among drivers/riders crashing in regional (7.6%) and remote Western Australia (15.6%).

Table 4.24 Seat belt/helmet use by drivers/riders* involved in serious injury crashes; by location, Western Australia, 2005-2009

Seat belt/helmet use	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Worn	10673	96.0	2378	92.4	1247	84.4	14298	94.3
Not worn	443	4.0	195	7.6	230	15.6	868	5.7
Total	11116	100.0	2573	100.0	1447	100.0	15166	100.0

n=4156 missing seat belt/helmet use. *Includes drivers and riders of known vehicle types, including bicycles, required to use a seat belt or helmet. Chi Square: X^2=950.35 df=2; $p \leq .001$.

Across all crash locations unprotected drivers and riders were nearly five times (OR=5.07 95% CI 4.14-6.19) more likely to be killed as opposed to non-fatally injured/no injury when involved in a serious injury crash. The unadjusted odds of an unprotected driver/rider being fatally *versus* non-fatally injured/no injury were highest for those crashing in the remote area (OR=5.46 95% CI 3.72-8.05) versus the regional (OR=3.98 95% CI 2.76-5.74) and metropolitan area (OR=3.67 95% CI 2.59-5.21). Only the remote and metropolitan areas significantly differed in the risk of death associated with the non-use of protection.

Multivariate analysis of the effect of various driver/rider (excluding bicycle riders) factors (sex, age, licensing status, BACL status) on the use of a seat belt/helmet use (worn *versus* not worn) was undertaken for each location and is reported in Table 4.25. Age of driver/rider was a significant risk factor for being unbelted only for those aged 25-39 years and crashing in regional WA (OR=2.57). Across all crash locations male drivers/riders and those recording a positive BACL were significantly more likely to be unbelted, with the risk varying across the locations. Being

unlicensed was a significant risk factor for drivers/riders being unbelted in crashes in the metropolitan (OR=2.33) and rural (OR=3.17) areas only.

Table 4.25 Driver demographics, licensing status and alcohol use associated with the non-use of a seat belt/helmet by drivers/riders involved in a serious injury crash in the metropolitan regional and rural areas; Western Australia 2005-2009

Location/Variable	OR	95% Confidence Interval	P value
Metropolitan Area			
Gender			
-Female^	1.0		
-Male	1.99	1.35-2.92	.000
Licence Status			
-Licensed^	1.0		
-Unlicensed	2.33	1.53-3.55	.000
BACL status			
-Zero	1.0		
-Positive	4.35	3.12-6.06	.000
Regional Area			
Age (years)			
-60+ ^	1.00		
-40-59	1.58	0.61-4.05	ns
-25-39	2.57	1.04-6.36	.040
-17-24	1.46	0.57-3.72	ns
Gender			
-Female^	1.0		
-Male	4.04	2.05-7.95	.000
BACL status			
-Zero^	1.0		
-Positive	5.16	3.22-8.28	.000
Rural Area			
Gender			
-Female^	1.0		
-Male	4.49	2.19-9.23	.000
Licence Status			
-Licensed^	1.0		
-Unlicensed	3.17	1.89-5.31	.000
BACL status			
-Zero^	1.0		
-Positive	3.10	1.94-4.96	.000

^reference group

4.2.5 Passengers

Information on passengers involved in a serious injury crash is only available when the passenger is noted by police to have sustained an injury. The details of uninjured passengers were otherwise not recorded during the study period. A total of n=5394 passengers were recorded by police to have been fatally or non-fatally injured when involved in a serious injury crash during the period 2005 to 2009, with the majority (55.7%) of injured passengers involved in serious injury crashes occurring in the

metropolitan area. The injury outcome, age, sex, and use of protection by passengers are presented in Tables 4.26-4.29.

4.2.5.1 Injury outcome

The majority (68.3%) of passengers involved in a serious injury crash sustained injuries that, according to police, required hospitalisation. A further 4.6% of passengers were reported to be fatally injured. The injury outcomes of passengers varied with the location of crash: passengers were more likely to be fatally injured in remote area crashes (7.8%) compared with regional (6.7%) and metropolitan area (2.5%) crashes, while passengers were somewhat more likely to be hospitalised as a result of metropolitan area crashes (70.6%) compared with regional (67.1%) and remote area (63.8%) crashes.

Table 4.26 Injury outcome of passengers involved in serious injury crashes; by location, Western Australia, 2005-2009

Injury Outcome	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Death	76	2.5	78	6.7	95	7.8	249	4.6
Medical attention	538	18.0	233	19.9	285	23.4	1056	19.6
Hospitalisation	2114	70.6	784	67.1	776	63.8	3674	68.3
Injury not requiring medical attention	268	8.9	74	6.3	61	5.0	403	7.5
Total	2996	100.0	1169	100.0	1217	100.0	5382	100.0

n=12 missing Injury Outcome; Chi Square: X^2=68.15 df=10; $p \leq .001$

4.2.5.2 Age

Just over 50% of all passengers involved in a serious injury crash were aged 17-39 years. A significant relationship was computed between age and location of crash. For example, a higher than expected proportion of passengers aged 17-24 years were involved in a crash in the metropolitan area, while a higher than expected proportion of passengers aged 25-39 and 40-59 years were involved in a crash in the remote area.

Table 4.27 Age of passengers involved in serious injury crashes; by location, Western Australia, 2005-2009

Age Group	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Up to 11 years	332	13.7	145	14.9	109	10.4	586	13.2
12-16 years	300	12.4	130	13.3	95	9.1	525	11.8
17-24 years	812	33.6	280	28.7	301	28.8	1393	31.4
25-39 years	424	17.5	182	18.7	281	26.9	887	20.0
40-59 years	293	12.1	134	13.8	164	15.7	591	13.3
60+ years	256	10.6	103	10.6	94	9.0	453	10.2
Total	2417	100.0	974974	100.0	1044	100.0	4435	100.0

n=959 missing Age; Chi Square: X^2=68.15 df=10; $p \leq .001$

4.2.5.3 Sex

The sex of passengers was not identified for 51.2% of those involved in a serious injury crash. Of the remaining, males and females were near equally distributed among crash involved passenger across all locations. A significant relationship was computed between sex of passengers and location of crash, with 60.1% of crash involved passengers in the remote area being male, compared with 44.9% in the metropolitan area and 49.2% in the regional area.

Table 4.28 Sex of passengers involved in serious injury crashes; by location, Western Australia, 2005-2009

Sex	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Males	634	45.0	292	49.5	377	59.8	1303	49.6
Females	775	55.1	298	50.5	253	40.2	1326	50.4
Total	1409	100.0	590	100.0	630	100.0	2629	100.0

n=2765 missing Sex; Chi Square: X^2=38.37 df=2; $p \leq .001$

4.2.5.4 Use of protection

Information on passenger seat belt use (or helmet use in the case of those riding pillion on motorcycles and bicycles) was not available for 18% of those recorded by police to be involved in a serious injury crash. Across all locations, 85.6% of injured passengers were reported to have used protection, though this proportion was lowest

for passengers involved in a crash in the remote area (66.2%) and highest for those involved in a crash in the metropolitan area (91.6%).

Table 4.29 Seat belt/helmet use by passengers involved in serious injury crashes; by location, Western Australia, 2005-2009

Seat belt/helmet use	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Worn	2249	91.6	889	89.1	641	66.2	3779	85.6
Not worn	206	8.4	109	10.9	328	33.8	643	14.4
Total	2455	100.0	998	100.0	969	100.0	4422	100.0

n=972 missing Seat Belt/Helmet Use; Chi Square: X^2=375.95 df=2; $p \leq .001$

As per driver/riders, passengers involved in a serious injury crash across WA were five times more likely to be fatally *versus* non-fatally injured if they were not using protection (seat belt or helmet): OR=5.01 95%CI 3.75-6.70. The odds of a passenger being killed in a metropolitan area serious injury crash when unbelted/not wearing a helmet (OR=3.92 95%CI 2.18-7.06) was not significantly different from those crashing in regional (OR=3.01 95%CI 1.64-5.51) or remote Western Australia (OR=5.91 95%CI 3.54-9.87).

4.2.6 Pedestrians

A total of n=1082 pedestrians were involved in a serious injury crash during the period 2005 to 2009, with the majority (77.3%) involved in crashes occurring in the metropolitan area. Injury outcome, age, and sex of crash involved pedestrian and the posted speed zone of the crash are reported in Tables 4.30 to 4.34. No analysis was undertaken of pedestrian BACL as this information was missing for 89% of crash involved pedestrians.

4.2.6.1 Injury outcome

Almost nine in ten pedestrians involved in a serious injury crash required hospitalisation (Table 4.30). As for drivers and passengers, the injury outcome of crash involved pedestrians varied with the location of the crash. Pedestrians were significantly more likely to be hospitalised when involved in a crash in the metropolitan area, while pedestrians were more likely to be killed when involved in a crash in the regional (13.3%) and remote area (17.4%), compared with the metropolitan area (7.4%).

Table 4.30 Injury outcome of pedestrians involved in serious injury crashes; by location, Western Australia, 2005-2009

Injury Outcome	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Death	62	7.4	18	13.3	19	17.4	99	9.2
Medical attention	15	1.8	2	1.5	2	1.8	19	1.8
Hospitalisation	751	90.2	114	84.4	88	80.7	953	88.5
Injury not requiring medical attention	5	0.6	1	0.7	0	0.0	6	0.6
Total	833	100.0	135	100.0	109	100.0	1077	100.0

n=5 missing Injury Outcome. Chi Square: X^2=105.40 df=6; $p \leq .001$

4.2.6.2 Age

Around 46% of all serious injury crash involved pedestrians were aged 17-39 years. The age of crash involved pedestrians was similar across the metropolitan and regional area. In contrast, pedestrians involved in crashes in the remote area were more likely to be aged 25-59 years and less likely to be under 17 years of age.

Table 4.31 Age of pedestrians involved in serious injury crashes; by location, Western Australia, 2005-2009

Age Group	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Up to 11 years	64	8.5	14	11.3	7	7.4	85	8.8
12-16 years	81	10.8	19	15.3	4	4.2	104	10.7
17-24 years	178	23.7	27	21.8	16	16.8	221	22.8
25-39 years	166	22.1	24	19.4	31	32.6	221	22.8
40-59 years	137	18.2	17	13.7	26	27.4	180	18.5
60+ years	126	16.8	23	18.5	11	11.6	160	16.5
Total	752	100.0	124	100.0	95	100.0	971	100.0

n=111 missing Age; Chi Square: X^2=21.36 df=10; $p \leq .05$

4.2.6.3 Gender

Around six in ten crash involved pedestrians were male. The distribution of males and females was similar across metropolitan and regional crashes. In the remote area however, males accounted for approximately three-quarters of those involved in a serious injury crash.

Table 4.32 Sex of pedestrians involved in serious injury crashes; by location, Western Australia, 2005-2009

Sex	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Males	487	61.5	78	59.1	74	74.0	639	62.4
Females	305	38.5	54	40.9	26	26.0	385	37.6
Total	792	100.0	132	100.0	100	100.0	1024	100.0

n=58 missing sex; Chi Square: X^2=6.63 df=2; $p \leq .05$

4.2.6.4 Posted speed zone

The posted speed zone of serious injury crashes involving pedestrians is presented in Table 4.33. In each location the majority of serious injury pedestrian crashes occurred on roads posted 60km/hour and below. Posted speed zone and location of crash were found to be associated, with a higher than expected number of pedestrian crashes observed in higher speed zones (e.g., ≥80km/hour) in the remote and rural area, and a higher than expected number of pedestrian crashes in the 60km/hour-70km/hour speed zone in the metropolitan area.

Table 4.33 Posted speed zone of serious injury pedestrian crashes; by location, Western Australia, 2005-2009

Speed Zone	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
40km/hour or less	18	2.9	3	2.8	1	1.1	22	2.7
50km/hour	274	43.4	52	47.7	47	54.0	373	45.1
60km/hour	231	36.6	20	18.3	15	17.2	266	32.2
70km/hour	66	10.5	12	11.0	3	3.4	81	9.8
80km/hour	29	4.6	7	6.4	4	4.6	40	4.8
90km/hour	3	0.5	5	4.6	4	4.6	12	1.5
100km/hour	9	1.4	1	0.9	1	1.1	11	1.3
110km/hour	1	0.2	9	8.3	12	13.8	22	2.7
Total	631	100.0	109	100.0	87	100.0	827	100.0

n=255 missing Speed Zone. Chi Square: X^2=109.85 df=14; $p \leq .001$

4.2.6.5 Time of day

The time of day of serious injury crashes involving pedestrians is presented in Table 4.34. A higher than expected number of pedestrian crashes occurred during the

period 18:00-23:59 in both the regional and remote locations, and higher than expected number in the period 00:00-05:59 in remote locations.

Table 4.34 Time of day of serious injury pedestrian crashes; by location, Western Australia, 2005-2009

Time of day	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
00.00-05:59	111	13.5	23	16.9	23	21.3	157	14.8
06.00-11:59	185	22.6	26	19.1	22	20.4	233	21.9
12:00-17:59	289	35.2	41	30.1	18	16.7	348	32.7
18:00-23:59	235	28.7	46	33.8	45	41.7	326	30.6
Total	820	100.0	136	100.0	108	100.0	1064	100.0

n=18 missing Time of Day. Chi Square: X^2=21.31 df=6; $p \leq .001$

4.3 Vehicle characteristics

Police crash records unfortunately contain minimal information that is useful for an analysis of vehicle factors relevant to a serious injury crash by location. The most useful information relates to the vehicle type and registration status. Other vehicle information, such as age of manufacture and number of cylinders, are mostly incomplete in police crash records and therefore of limited use.

4.3.1 Vehicle Type

As shown in Table 4.35, nearly 85% of vehicles involved in a serious injury crash across all locations were passenger type vehicles. Motorcycles (inclusive of mopeds and trail bikes) accounted for a further 8.4% of serious injury crash involved motorised vehicles, while trucks (including arrangements of prime movers, trailers and road trains) accounted for another 3.6% of vehicles. There was some variation in vehicle type by location of crash: motorcycles and bicycles were more frequently involved in metropolitan crashes, while trucks and buses were more frequently involved in remote area crashes.

Table 4.35 Vehicles* involved in serious injury crashes; by location, Western Australia, 2005-2009

Unit Type	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Passenger Car	14168	84.2	3612	84.8	2564	84.8	20344	84.8
Motorcycle/mopeds	1473	8.8	367	8.6	194	6.4	2034	8.4
Truck	487	2.9	199	4.7	181	6.0	867	3.6
Bicycle	487	2.9	61	1.4	18	0.6	560	2.3
Bus	191	1.1	14	0.3	59	2.0	264	1.1
Other	24	0.1	7	0.2	7	0.2	38	0.2
Total	16824	100.0	4260	100.0	3023	100.0	24107	100.0

*Excludes non-motorised scooters and skateboards. Chi Square: X^2=220.64 df=10; p ≤ .001

4.3.2 Vehicle Registration Status

Registration status was analysed for cars, trucks, buses, motorcycles, moped and motorbikes. Over 99% of motorised vehicles involved in a serious injury crash were registered at the time of the crash. The proportion of unregistered crashing vehicles was slightly higher in regional and remote Western Australia and contributed to a significant association between registration status and location of crash.

Table 4.36 Registration status of motorised vehicles involved in serious injury crashes; by location, Western Australia, 2005-2009

Registration Status	Location							
	Metropolitan		Regional		Remote		All Areas	
	n	%	n	%	n	%	n	%
Registered	13010	99.5	2930	98.8	1693	98.0	17633	99.3
Unregistered	62	0.5	37	1.2	34	2.0	133	0.7
Total	13072	100.0	2967	100.0	1727	100.0	17766	100.0

n=446 missing registration status; Chi Square: X^2=57.76 df=2; p ≤ .001

4.4 Multivariate analysis of serious injury crash risk by location

The aim of the multivariate analysis was to investigate if groupings of crash and road factors and groupings of driver/rider factors could predict or discriminate serious injury crashes in each of the three locations. For this analysis, Multinomial Logistic Regression (MLR) was used in preference to Discriminant Function Analysis (DFA) since the former does not require assumptions of normality, linearity, and homogeneity of variance for the independent or predictor variable, which are required for DFA. For the analysis, the metropolitan area was selected as the 'reference location' (see Tables 4.37 and 4.38).

4.4.1 Crash and road factors

The Likelihood Ratio Test confirmed a statistically significant relationship between four crash/road variables and the location of the occurrence of the serious injury crash. Compared with the metropolitan Perth area, serious injury crashes in the regional and remote areas were significantly more likely to involve a single vehicle rather than multiple vehicles/units (OR=1.65 ^{regional}; OR=3.0 ^{remote}), to occur on unsealed rather than sealed roads (OR=6.51 ^{regional}; OR=19.0 ^{remote}), on curves rather than straight sections of road (OR=2.15 ^{regional}; OR=2.35 ^{remote}), and on roads with posted speed limits of ≥90km/hour compared with ≤80km/hour (OR=9.21 ^{regional}; OR=12.01 ^{remote}). Comparison of the odds ratios and 95% confidence intervals of variables across the regional and remote locations shows that for all variables, except road alignment, the odds ratios were consistently higher for remote area crashes than those for regional area crashes.

Table 4.37 Multinomial Logistic Regression of metropolitan*, regional and remote serious injury crashes by crash and road factors; Western Australia, 2005-2009

Location/Variable	Odds Ratio	95% Confidence Interval	(P)
Regional WA			
Type of crash			
-Multiple Unit^	1.00	-	-
-Single Unit	1.65	1.43-190	<0.001
Road Surface			
-Sealed^	1.00	-	-
-Unsealed	6.51	3.97-10.67	<0.001
Road Alignment			
- Straight^	1.00	-	-
-Curved	2.15	1.87-2.48	<0.001
Posted Speed Limit			
-≤80km/hour]^	1.00	-	-
-≥90km/hour	9.21	8.08-10.49	<0.01
Remote WA			
Type of crash			
-Multiple Unit^	1.00	-	-
-Single Unit	3.00	2.54-3.54	<0.001
Road Surface			
-Sealed^	1.00	-	-
-Unsealed	19.09	11.82-30.84	<0.0001
Road Alignment			
-Straight^	1.0	-	-
-Curved	2.35	1.97-2.81	<0.001
Posted Speed Limit			
-≤80km/hour^	1.00	-	-
-≥90km/hour	12.01	10.27-14.05	<0.001

*Metropolitan area is the *reference category* location. ^Reference value
-2 Log Likelihood= 263.64, χ^2=3101.31, df=8, p<0.001;

4.4.2 Driver/rider factors

The Likelihood Ratio Test confirmed a statistically significant relationship between four driver/rider variables and the location of the occurrence of the serious injury crash, particularly for crashes occurring in remote WA compared with metropolitan WA. Compared with crashes in the metropolitan area, increased odds of involvement in a serious injury crash in the *remote* area were identified for male drivers (OR=1.25); drivers aged 25-39 years (OR=1.43); drivers recording a BACL of ≥0.101gm% (OR=2.54), 0.05gm%-0.100gm% (OR=1.54) and 0.001gm%-0.49gm% (OR=1.48), and drivers who did not hold a valid licence at the time of the

crash (OR=2.13). Whilst driver sex and driver licence status were not significantly associated with serious injury crashes in the regional area compared with the metropolitan area, driver age and BACL were. Increased odds of involvement in a serious injury crash were identified for drivers aged 40-59 years (OR=1.36), while drivers aged 17-24 years showed reduced odds of crashing (OR=0.86). As for the remote area, all positive levels of BAC were associated with an increased odds of crashing: ≥0.101gm% (OR=1.72); 0.05gm%-0.100gm% (OR=1.70), and 0.001gm%-0.049gm% (OR=1.55) These findings highlight the linear relationship between BACL and crashing in both the regional and remote areas, with the risk of crashing associated with the highest level of BAC being greatest in the remote area. The other notable difference between the two non-metropolitan areas is the higher odds of unlicensed drivers being involved in a remote area serious injury crash.

Table 4.38 Multinomial Logistic Regression of metropolitan*, regional and remote serious injury crashes by driver/rider+ factors; Western Australia, 2005-2009

Location/Variable	Odds Ratio	95% Confidence Interval	(P)
Regional WA			
Driver Sex			
-Female^	1.00	-	-
-Male	1.10	0.90-1.23	ns
Driver Age+			
-60+ years^	1.00	-	-
-40-59 years	1.36	1.15-1.60	<0.001
-25-39years	1.05	0.91-1.23	ns
-17-24 years	0.86	0.75-0.98	<0.05
Blood Alcohol Concentration Level			
-0.000gm%^	1.00	-	-
-≥ 0.101gm%	1.72	1.40-2.10	<0.001
-0.05-0.100gm%	1.70	1.33-2.19	<0.001
-0.001-0.049gm%	1.55	1.18-2.06	<0.01
Driver Licence			
-Valid licence^	1.0	-	-
-No valid licence	0.86	0.69-1.08	ns
Remote WA			
Driver Sex			
-Female^	1.00	-	-
-Male	1.25	1.07-1.45	<0.01
Driver Age+			
-60+ years^	1.0	-	-
-40-59 years	0.92	0.70-1.20	ns
-25-39years	1.43	1.19-1.70	<0.001
-17-24 years	1.04	0.88-1.25	ns
Blood Alcohol Concentration Level			
-0.000gm%^	1.00	-	-
-≥ 0.101gm%	2.54	2.05-3.16	<0.001
-0.05-0.100gm%	1.54	1.11-2.13	<0.05
-0.001-0.049gm%	1.48	1.03-2.13	<0.05
Driver Licence			
-Valid licence^	1.0	-	-
-No valid licence	2.13	1.73-2.63	<0.001

*Metropolitan area is the *reference category* location. ^Reference value +Excludes drivers under 17 years and bicycle riders. -2 Log Likelihood=483.56, χ^2=248.33, df=20, p<0.001

5. DISCUSSION

5.1 Introduction

The aims of this investigation were to report the distribution of serious injury crashes across the metropolitan, regional and remote areas of Western Australia and to identify possible explanatory factors for the variation in the distribution. Based on police reported crashes for the period 2005-2009 this study identified significant variation in the distribution of serious injury crashes across Western Australia and varying evidence in relation to the involvement of road/environment, speed, vehicle, and road user behavioural factors across the three locations. In the following sections the findings will be discussed and recommendations made for further research.

5.2 The association between location of crash and crash severity

In keeping with the findings presented in the literature review of an association between crash severity and location of crash, this investigation similarly noted a significant relationship between crash location and severity. When considering *all crashes* recorded by WA Police during the period 2005-2009, fatal and hospitalisation crashes – collectively regarded as serious injury crashes in this study – were proportionally higher in the regional and remote areas. Less than 5% of crashes occurring in the metropolitan area resulted in either the death or hospitalisation of an involved road user compared with 9.6% of crashes in the regional area and 14% of crashes in the remote area. Indeed, a crash in the regional and remote areas was respectively two to three times more likely to result in a serious injury compared with a crash in the Perth metropolitan area. Even more troubling was the finding that the seriously injured road user was three to 4.5 times more likely to be killed if the crash occurred in regional and remote Western Australia respectively compared with metropolitan Perth.

While these findings clearly exemplify the greater risk of serious injury for those involved in crashes in the regional and remote areas of Western Australia, the majority of the road injury burden, because of the absolute numbers of road users injured, can still be attributed to travel and crashes within the metropolitan area. This however, does not discount the need to understand the additional risk of serious injury crashes in the non-urban area and to propose appropriate countermeasures.

In the following sections the factors identified to be associated with serious injury crashes by location will be discussed in relation to the Safe System framework to elucidate the role of these factors in the differential pattern of crashes and to inform relevant countermeasures.

5.3 Safe Roads and Roadsides

Improving the quality of roads and maintaining safe and hazard-free roadsides is integral to reducing the incidence of crashes and the severity of injury (Elvick et al., 2009) and is a cornerstone of the State's *Toward Zero* road safety strategy. In keeping with this theme, a number of road and roadside factors were found to be associated with the distribution of serious injury crashes across the State.

Crashes at intersections, particularly those involving right angle and right turn thru vehicle movements, were the main crash type for serious injury crashes in the metropolitan area. This finding is reasonably consistent with research elsewhere and locally. Indeed the problem of serious injury crashes at metropolitan intersections was investigated in greater detail by Main Roads Western Australia (2009) through a micro analysis of the top 20 metropolitan traffic light controlled intersections for serious injury crashes, 2003-2007. The aims of the analysis were to identify the characteristics of serious injury crashes in each intersection and to consider if and how the layout and infrastructure of the particular intersection contributed to the pattern of crashes and what 'treatments' could be effected to reduce future serious crashes. Right angle, right turn thru, and rear end crashes were noted to be the predominant crash types across the 20 intersections. Recommended short, medium and long term treatments, including cost-benefit calculations, to address these crash types were subsequently proposed. Examples of the recommended treatments included:

- increasing the signal clearance time;
- the installation of red light cameras to deter red light running;
- the reduction of speed limits through the intersection;
- speed cushions at the intersection;
- right turn with green arrow only;
- modifying lane configurations; and the

- removal of vegetation to improve sight lines.

The strength of the micro analysis approach, though intensive and costly, is that it permits a detailed analysis of the relationship between the circumstances of the crashes and the specific environmental and traffic engineering conditions of the particular intersection, which this analysis was not able to do.

Though there is no information to hand to indicate the extent to which the broad ranging recommendations of the micro analysis have been adopted across the 20 intersections reviewed so far, the process highlights the commitment of the State in addressing serious injury crashes at metropolitan intersections. The status of the recommendations for the previous micro analysis should nevertheless be reviewed and consideration given to continuing the process for an in-depth review of the next 20 ranked metropolitan intersections for serious injury crashes.

Future micro analysis reviews should adopt the four key principles proposed by Corben (2010) for improving safety at intersections and reducing crashes. Corben (2010) considers that traffic engineers should firstly look to reduce the number of vehicles using the intersection. Secondly, the road network should be designed to limit the need for intersections. Thirdly, intersections should be designed so there are few opportunities for conflict between vehicles. Lastly, speeds at intersections and potential impact angles should be engineered to lessen impact forces to levels that are biomechanically tolerable. Countermeasures that could be applied that are consistent with these principles include: the installation of roundabouts; raised platforms and stop line speed humps to reduce vehicle speeds; grade separation of traffic (e.g., bridges at major intersections (Corben, 2010); reduced speed limits through intersections (OECD, 2008); red light cameras (Retting, Ferguson & Hakkert, 2003) and dual speed and red-light cameras to reduce red light running and travel speeds (Brimson & Anderson, 2002; Budd et al., 2011).

In contrast to crashes at metropolitan intersections which involve conflict between vehicles, this study identified that regional and remote area serious injury crashes more commonly involved single vehicle crashes where the vehicle left the road on a curve or straight, rolled over, or hit a roadside object such as tree/shrub or embankment. Indeed the multivariate analysis of the data showed that serious injury crashes in the regional and remote areas were respectively 65% and three times more

likely to involve a single vehicle compared with crashes in the metropolitan area, and twice as likely to occur on a curve in both the regional and remote area compared with the metropolitan area. Not so surprisingly, serious injury crashes in both the regional and remote area were substantially more likely (6.5 to 19 times) to occur on unsealed roads compared with those in the metropolitan area. These crash scenarios are again consistent with those identified elsewhere for non-urban area crashes and highlight the need for measures to reduce the incidence of vehicles leaving the road and rolling over or colliding with non-frangible objects like trees.

Previous research has identified a variety of risk factors for single vehicle run off road crashes, including driver impairment (e.g., fatigue, alcohol, illicit drugs); road conditions (e.g., pavement edge drop off; poor delineation; loose material) and inappropriate vehicle speed (ARRB, 2011). Unfortunately it was not possible to reliably investigate the contribution of the preceding factors to run off road crashes in the regional and remote areas in this study. A more comprehensive dataset based on Coroner's and crash reconstruction investigations might provide the detail required at an individual crash level. Despite the absence of evidence to ascertain the precise cause of run off road crashes in this study, a number of effective countermeasures can be generally applied to reduce the incidence of and consequence of run off road crashes in the non-urban areas of Western Australia. These include sealed shoulders, audible edge lining, clear zones, road side barriers, and improved curve delineation.

Sealed shoulders and audible edge lining have been found to reduce the incidence of all severity crashes in rural areas by up to 58% with an estimated cost-benefit ratio of 40.3 (Meuleners et al., 2011). Second to these measures, clear zones and barriers are known to effectively reduce the severity of injury should the vehicle leave the road by limiting the opportunity to collide with hazardous objects (Szwed, 2011). In regard to barriers, flexible wire rope barriers are regarded as the most comprehensively effective measure to reduce the severity of injuries associated with run off road crashes (Corben, 2004), contributing to casualty and serious injury crash reductions of up to 87% (Candappa, D'Elia, Corben & Newstead, 2011). Similarly, initiatives such as signage, road markings and chevrons to improve the delineation of horizontal curves to assist drivers in maintaining appropriate positioning and speed through the curve have been found to reduce the incidence of crashes and crash severity on rural roads, with a cost-benefit ratio of 8:1 (FHWA, 2009).

The above discussion has highlighted the effectiveness of a range of countermeasures to reduce the incidence of run off road crashes and injury severity on regional and remote roads, and further, opportunities for reducing the incidence of serious injury crashes at metropolitan intersections. At present, Main Roads Western Australia (MRWA) administers a number of programs such as the *Nation, State and Local Road Black Spot* programs and the *Safer Roads Program* which aim to identify and treat roads to reduce crashes and injury severity. Road treatments funded under these programs have to date included initiatives to reduce metropolitan intersection crashes and run off road crashes in regional and remote areas. These programs are instrumental to the advancement of safer roads across Western Australia, thus, it is incumbent on both MRWA and local government – who together share responsibility for the improvement of the State road network- to continue to advocate for increased funding for these programs and to apply for program funds to improve the safety of roads in locations identified by the respective road owners as having a high serious injury crash risk.

5.4 Safe Speeds

Excess and inappropriate speeds have been consistently identified as significant risk factors for the occurrence of a crash and the severity of any resulting injury (Kloeden, McLean, Moore & Ponte, 1997; Kloeden, Ponte & McLean, 2001; Aarts & van Schagan, 2006). It is hypothesised that high travel speeds increase the risk of a crash firstly because drivers may lose control of the vehicle and secondly because the distance travelled during the time taken to react and brake is increased which therefore increases the distance required to stop (Kloeden et al., 2001). The Safe Systems approach to road safety consequently seeks to apply lower and more appropriate speed limits to minimise the risk of crashing and to lessen impact forces to more tolerable, survivable levels in the event of a crash to reduce injury severity. In support of this, calculations by Nilsson (2004) estimate that even a 5% reduction in average vehicle travel speeds can hypothetically result in a 10% reduction in all injury crashes and a 20% reduction in fatal crashes.

This study was unfortunately limited in regards to the investigation of speed as an explanatory factor for the variation in serious injury crashes across the Western Australia because of the lack of valid and reliable information on speed as a contributing factor as reported by police. Alternatively, the speed zone of the road at

the location of the crash was considered as a proxy measure of speed involvement. It was found that around six in ten serious injury crashes in the metropolitan area occurred in speed zones of 60km/hour or less. In contrast, between 50% and two thirds of serious injury crashes in the regional and remote areas occurred in speed zones of 100km/hour and higher. Moreover, the multivariate analysis showed that serious injury crashes in the regional and remote areas were substantially more likely (between nine and twelve times) to occur in higher speed zones (≥90km/hour) compared with those in the metropolitan area, even after adjusting for the type of crash, road surface, and road alignment.

These finding are consistent with those reported by Tziotis et al. (2006) and others of the relatively greater involvement of higher speed zones and speeds in crashes occurring on rural and remote area roads. On the assumption that these crashes will have occurred at the maximum posted speed or close to it (if not higher), speed is strongly implicated in the higher prevalence of a serious injury in regional and remote area crashes in these locations relative to the metropolitan area. Unfortunately it was not possible to develop rates of serious injury crash involvement per kilometre of speed zone across the locations to adjust for differences in the distribution of speed zones.

The increased risk of a serious injury crash associated with a higher speed zones in the regional and remote locations does not in itself suggest that speed is any less an important factor in the occurrence of serious injury crashes in the metropolitan area. Indeed, a recent unpublished analysis by Holman (2011) of the relationship between illegal speeding and serious injuries in 60km/hour and 110km/hour speed zones in Western Australia identified that "..speeding causes a lower proportion of serious crashes in regional 110km/hour zones than in metropolitan 60km/hour zones: 22% versus 52% (page 4). Holman's (2011) analysis confirms that low level speeding in metropolitan areas is particularly problematic, especially given the likelihood that crashes in the metropolitan area are more likely to involve multiple vehicles in conflict situations such as intersections. However, the higher travel speeds in regional and remote area crashes means that crashes are more likely to occur at higher impact speeds, thus increasing the risk of a severe injury to occupants. In the regional and remote area, this risk is exacerbated by a higher likelihood that vehicle

occupants in these localities will be unbelted (see Roberts et al., 2006 and Oxley et al., 2009).

The challenge for Western Australia under the *Toward Zero* strategy is to implement initiatives that reduce travel speed, both in terms of lower and more appropriate speed zones, and to ensure that vehicles keep to the posted speed limit. The finding in this study of a relationship between the posted speed zone at the crash site and the geographic location of the crash highlights the need in the first instance to consider the *appropriateness of existing speed limits* in the regional and remote areas. This is not to suggest a blanket reduction in the maximum speed limit (110km/hour) is warranted. Rather, it is suggested that MRWA review the non-urban road network to identify roads currently zoned to the maximum speed of 110km/hour but are less than appropriate for such speeds because of:

- inadequate roadside treatments (sealed shoulders, clear zones and barriers,) to reduce run off road crashes and injury severity, and;
- an inability to separate vehicles from opposing direction (medians, barriers) to reduce the chances of head-on collision.

Indeed it has been suggested that a 70km/hour speed limit be applied to two-way roads without separation to reduce the severity of head on crashes (OECD, 2008). However, it may be more feasible and acceptable to the community to introduce a reduction from 110km/hour to 80km/hour on secondary regional and remote roads that lack the necessary treatments to reduce the likelihood of run off road and head on crashes at speeds that increase the risk of more serious injuries. Further to this, given the identified high risk of serious injury crashes associated with unsealed roads in the regional and remote area, it would also be appropriate to limit the maximum speed on unsealed roads to 80km/hour. Admittedly this would be difficult to enforce given the remoteness of most unsealed roads.

Second to initiatives to selectively reduce speed limits on high risk regional and remote roads, there is good reason to consider that vehicle speeds in these area could be better managed and serious injury crash reductions achieved through *strategic speed enforcement* (Kloden et al., 2001). At present, WA Police are in the process of implementing a comprehensive, targeted program of speed enforcement across

Western Australia. The program, proposed by Cameron & Delaney (2006) and Cameron (2008), represents best practice in speed enforcement using a variety of automated enforcement activities including fixed black spot speed cameras, dual red-light/speed cameras at intersections, and point to point camera operations. There is good evidence to show that automated speed enforcement activities can reduce both the incidence of crashes and injuries (Wilson, Willis, Hendriks & Bellamy, 2009) and would thus likely contribute to a reduction in speed related serious injury crashes in the regional and remote area if and when the enhanced speed enforcement program is extended to these areas. For example, modelling undertaken by Cameron (2010) shows that fixed speed cameras applied to major road links 5-10km long can significantly reduce crashes and associated costs, with a cost-benefit ratio of 1:1.3.

A program of strategic speed enforcement on the typically less enforced regional and remote roads of Western Australia should necessarily involve the co-operation of the local government sector since they have ownership of approximately 50% of roads in the regional and remote areas on which serious injury crashes in this study occurred. One recent suggestion by Palamara (2011) to the local government sector and WA Police is for local government to undertake a more strategic approach to measuring vehicle travel speeds in their localities and supply timely information on problem area speeding to police to facilitate targeted camera and non-camera based enforcement.

5.5 Safe Vehicles

Improving the safety of vehicles and increasing the uptake of safer vehicles by road users is a key cornerstone of the Safe System response to road injury. To this end, the Western Australian *Toward Zero* road safety strategy promotes the use of vehicles with crash avoidance features (such as Anti-lock Braking Systems, Electronic Stability Control, Traction Control) to reduce the incidence of crashing, and advanced crash worthiness and occupant protection systems (such as multiple airbags) to reduce the severity of injury in the event of a crash. Unfortunately, this study was not able to comprehensively address the range of vehicle factors that may have contributed to the over-representation of serious injury crashes in remote and regional areas compared with metropolitan area. The crash data used for this project did not contain information on the prevalence of crash avoidance features or the crash worthiness ratings of vehicles.

Previous research (e.g., Tziotis et al., 2006) has noted that older and consequently lower crashworthy vehicles were more commonly involved in fatal crashes in rural Victoria compared with metropolitan Melbourne. This was presumed to be due in part to the lower socioeconomic status of rural area residents and their ability to afford new and safer vehicles. Whilst WA Police do record the age of vehicles involved in a serious injury crash, this information was found to be incomplete for many serious injury crash records used in this study and therefore unsuitable for analysis.

This study did however identify variation across the locations in the distribution of certain vehicle types in serious injury crashes, namely the involvement of trucks. Consistent with the findings of other studies (e.g., Meuleners, 2009) this study noted that trucks were more likely to feature in the serious injury crashes occurring in regional (4.7%) and remote (6%) areas compared with the metropolitan area (2.9%). One explanation for this finding may be the higher exposure of trucks on non-urban roads but other evidence also indicates that the crash risk for trucks and heavy vehicles is due to a number of work environment, vehicle, and driver related factors and a complex interplay between them, particularly for non-urban area crashes. This literature was recently reviewed by Meuleners & Fraser (2012) and highlighted among many things the unique nature of the truck and heavy vehicle industry in Western Australia where vast distances between locations underscore the involvement of known crash risk factors such as driver fatigue, associated driver sleep disorders, and adverse working conditions. A detailed national investigation of non-fatal heavy vehicle crashes, including those in Western Australia (see Stevenson et al., 2010) is near completion and is likely to provide a range of recommendations for countermeasures to reduce heavy vehicle crash involvement.

Notwithstanding the absence of detailed information in this study on vehicle factors associated with serious injury crashes across WA, there is considerable information and evidence regarding the features of safer vehicles that would assist in the reduction of the higher incidence of loss of control, run off road serious injury crashes in regional and remote Western Australia. For example, crash avoidance technologies such as intelligent speed adaptation, lane departure warning, and fatigue monitoring systems will likely reduce single vehicle crashes with estimated reductions in crashes between 10.8% and 4.3% depending on the crash type

(Langford, 2009). Other evidence suggests that a combination of anti-lock braking systems and electronic stability control will prevent a large proportion of both fatal and non-fatal crashes, particularly in relation to single vehicle crashes (Kahane & Dang, 2009).

Over the years there has been a general increase in the crashworthiness of vehicles. For example, vehicle manufactured between 2003 and 2007 are considered to be three times safer than those manufactured in the period 1964-1973 (Langford, 2009). This trend and the increasing availability of crash avoidance technologies mean that the safety of the vehicle fleet will continue to steadily increase (Langford, 2009). The challenge is to quickly and comprehensively promote the uptake of safer vehicles, particularly among at risk groups, to help reduce certain crash types such as run off road single vehicle crashes in non-urban areas and the severity of injury in the event of a crash.

5.6 Safe road use and users

Reducing the incidence of unsafe, risky on-road behaviours and protecting vulnerable, 'at risk' road user groups are key concerns of the Safe System and the *Toward Zero* strategy of the State. This study has provided some evidence in relation to road users and the safety of their behaviours that in part explains the greater incidence of serious injury crashes in the non-urban area. The examination of these factors in this study was limited to the investigation of road user status, demographic factors such as age and gender, and behavioural factors such as unlicensed driving, driver/rider alcohol levels, and the non-use of seat belts/helmets. Unfortunately, no investigation could be undertaken of behavioural factors such as inattention and fatigue which are known to be associated with crashes occurring in non-urban areas of Australia (see Tziotis et al., 2006).

Whilst other studies have identified males and those of a younger age as risk factors for crashes in the non-urban areas (e.g., Hamilton & Kennedy, 2005; Tziotis et al., 2006;) there was less convincing and consistent evidence in this study for those two factors to distinguish serious injury crashes in the non-urban areas of Western Australia from those occurring in the metropolitan area. Serious injury crashes occurring in the regional area were not significantly more likely than those occurring in the metropolitan area to involve male drivers/riders. However, males were 25%

more likely to be driver/riders of vehicles involved in a serious injury crashes in remote WA relative to metropolitan Perth. This could be because females in remote areas (particularly Indigenous) are less likely to be licensed or to drive less often, or, that males engage in greater risk taking behaviours which thus increases their risk of crashing. This point will be reconsidered in the discussion below of drink-driving, unlicensed driving, and seat belt use

There was also no consistent evidence to show that younger age drivers/riders were significantly more likely to be involved in crashes in regional and remote areas compared with metropolitan Perth. This is contrary to other studies where younger age drivers (under 25 years) accounted for the greater proportion of crash involved drivers in rural Victoria (Symmonds, Haworth & Johnston, 2004). Males aged 40-59 years (regional area crashes) and males 25-39 years (remote area crashes) were significantly more likely to be involved in a serious injury crash compared with their same aged counterparts crashing in metropolitan Perth. Again, this finding could be related to patterns of risk taking by non-urban drivers/riders and/or driving exposure.

Consistent with previous research, serious injury crashes in the regional and remote area were more likely to be associated with certain risky road user behaviours compared with serious injury crashes in metropolitan Perth. Strong evidence was found to show that serious injury crash involved drivers/riders in the regional and remote areas, more so than those involved in metropolitan crashes, were more likely to record a positive BACL, to be unlicensed, and to be unbelted at the time of the crash.

In relation to alcohol, regional and remote area drivers/riders involved in a serious injury crash were 1.7 time to 2.5 times more likely than crashing metropolitan drivers to record the highest level of BAC ($\geq$ 0.101gm). Moreover, certain groups of regional and remote area drivers, such as males, younger age drivers, and the unlicensed, were noted to have a higher involvement of positive BACL levels. Why alcohol per se and higher BAC levels are a greater problem in the non-urban area is open to speculation. The reasons for this could include the absence of viable alternative transport in these areas; limited surveillance and detection of drinking drivers, and greater tolerance and acceptance of drinking and driving by members of these communities. Further investigation of these possible explanations and others is

required to determine how best to reduce the greater incidence of drink driving outside of metropolitan Perth and the risk of crashing.

While research has identified unlicensed driving to be a significant risk factor for crash involvement (see Palamara et al., 2012), no information was noted in the review of previous research to suggest a higher incidence of unlicensed driver among the crashes in regional and remote area. In this study drivers/riders without a valid licence accounted for 6.1% and 6.9% of drivers/riders crashing in the metropolitan and regional areas and 15.7% of drivers/riders crashing in remote WA. Other analyses showed that in all locations males were significantly more likely than females to be unlicensed at the time of the crash. There was also some evidence to suggest that younger age drivers/riders (17-24 years and 25-39 years) in all locations were significantly more likely to not be validly licensed at the time of the crash. This finding appears to be most robust and reliable for drivers/riders crashing in the remote area. From the information contained in the IRIS database it would seem that most crashing drivers/riders in remote WA without a valid licence had never obtained or held a driver/rider licence. This immediately suggests that existing programs and processes to facilitate driver/rider licensing in remote WA should be reviewed to determine if and how they could be improved.

There are a number of hypothetical reasons why unlicensed drivers are likely to have an increased risk of crashing, among them being a lack of certified driving skill if they have never held a licence, and/or an increased likelihood of engaging in other risky on-road behaviours if such behaviours contributed to the cancellation or suspension of the licence. In relation to this last point, this study did note that unlicensed drivers involved in a serious injury crash in all areas, particularly in regional area, had a significantly higher likelihood of a positive BACL compared with licensed drivers.

Consistent with the previous findings of a higher incidence of unlicensed and alcohol involved driving among drivers/riders crashing in regional and remote WA, this study also identified that the non-use of seat belts and helmets for drivers/riders was relatively higher among those crashing in the regional and remote areas. This finding might partially explain the relatively higher incidence of fatalities in these areas given that unprotected drivers/riders are five times more likely than protected

drivers/riders to be fatally as opposed to non-fatally injured. Once again, male drivers/riders were significantly more likely than females to not use protection at the time of the crash, with males in the regional and remote areas having a significantly higher risk of non-use than their metropolitan area counterparts. It was also noted that crashing drivers/riders in each location without a valid licence and those testing positive for alcohol were significantly more likely than licensed and alcohol free drivers/riders to not use protection.

The finding in this study that non-metropolitan crash involved drivers, and even passengers, have a higher likelihood of being unbelted is also consistent with previous WA research of crashing drivers and crash involved passengers undertaken by Oxley et al., (2009). The noted association of alcohol and unlicensed driving with failure to wear a seat belt portrays an image of increased risk taking among drivers in these locations relative to those in the metropolitan area. If this is so, it might also help explain why serious injury crashes, and in particular fatal crashes, are more prevalent in these locations. Why WA drivers in the non-urban areas are proportionally more likely to engage in these concurrent risk behaviours is open to speculation and further investigation. One possible contributing reason is because non-urban and urban area drivers differ in their attitudes toward road safety and risk taking behaviour and perceptions of the risk of detection. Previous research by Rakauskas et al. (2009) found that rural drivers compared with urban drivers in the USA were significantly more likely to not use a seat belt, to engage in more deliberate violations, to more frequently speed above the speed limit, and to consider that traffic law enforcement was less useful. Irrespective of the attitudes and perceptions of WA non-urban drivers there is a clear need for greater management of risk taking behaviour in these areas. This could include increased levels of 'targeted' enforcement and appropriate community based education programs to promote appropriate safety behaviours in the remote areas of WA where levels of enforcement are compromised because of fewer resources and an expansive road network. Initiatives such as these were also proposed by Austroads (2001) in their review of the non-use of seat belts on remote area roads in Australia..

In addition to the above driver issues, injuries to pedestrians are also relevant to the discussion of the variation in serious injury crashes across the three regions. Serious injuries to pedestrians accounted for around 4% of all injured road users during the

study period 2005-2009. They most commonly occurred in the metropolitan area (77.3%) compared with the regional (12.5%) and remote area (10.2%). The weight of these numbers initially suggests that the bulk of countermeasures to reduce pedestrian injuries should be concentrated in the metropolitan area, particularly in relation to lowering speeds around high pedestrian activity areas to survivable levels. It is important to note however, that pedestrians were significantly more likely to be killed in remote and regional area crashes compared with the metropolitan area crashes. This is perhaps because of the greater exposure of pedestrians in these locations to higher speed zones. For example, around 24% of pedestrian crashes in the remote area occurred in a 80km/hour or greater speed zone, with nearly 14% at the maximum speed limit, compared with 6.7% of crashes in the metropolitan area in equivalent zones. This finding, along with the higher relative likelihood of a pedestrian in the remote and regional areas being injured at night, also suggests that greater attention must be given to the types of roads pedestrians access in the non-urban area, particularly at night, and how best to separate them from high speed traffic and be more visible to drivers.

5.7 Methods Issues

There are a number of methodological issues in relation to the data used to identify serious injuries and the location of serious injury crashes and the factors related to serious injuries. These issues temper the validity of the findings and are briefly discussed below.

For pragmatic reasons, serious injury crashes were defined as those involving the police reported death or hospitalisation of an involved road user. No attempt was made to validate these injury outcomes through linkage with official death and hospital separation records. Previous research by Rosman and Knuiman (1994) comparing WA Police reported level of injury severity with those from hospital discharge files noted that police hospitalisation data was less reliable and at times under-reported the admissions and injury severity of certain road user groups. Hence there is some uncertainty regarding the accuracy of the police data used in this investigation, particularly in relation to hospitalisations.

The categorisation of the crash location into metropolitan, regional and remote areas based on the Accessibility/Remoteness Index of Australia (ARIA) (ABS, 2007) may

not necessarily represent the best measure of location. For example, the ARIA index does not take into account the time taken to obtain treatment or the form of transport used to travel to an appropriate treatment facility. Regional variations in post-crash care and treatment could not be considered in this investigation and are likely to have contributed to the severity of crashes noted in this study. Previous research has noted that variation in medical care post-crash is a significant contributor to the higher incidence of fatalities among road users in rural areas (Muelleman, Wadman, Tran, Ullrich & Anderson, 2007).

The use of IRIS crash data has also imposed limitations on the investigation, particularly in relation to driver behavioural factors such as illegal speeding and fatigue, and the inability to describe crash involved vehicles in relation to crash avoidance and occupant protection systems. The level of variation across the locations in serious injury crashes that can be potentially attributed to these factors could not be investigated in this study

6. RECOMMENDATIONS

This study noted a range of safer roads, safer speeds, safer vehicle, and safe road use factors that go some way towards explaining the identified variation across the Western Australia in the distribution of serious injury crashes. It is clear however, that additional research is required using a variety of methods to further elucidate the causes of and potential countermeasures for serious injury crashes across WA. The following recommendations for future research were developed after consultation with the WA Office of Road Safety.

Safer Roads and Roadsides

1. Expansion of the Main Roads WA micro analysis of serious injury crashes at metropolitan intersections to further investigate the contribution of road and driver factors to crashes at intersections.

   This study noted that one in five serious injury crashes in the metropolitan area occur at intersections, with around four in ten serious injury crashes involving vehicles colliding at right-angles. The first tranche of 20 metropolitan intersections investigated by the micro-analysis noted a number of potential contributing factors and made recommendations for cost-effective treatments. It is recommended that the micro-analysis be extended to the next 20 intersections for serious injury crashes.

2. Further research to identify new and innovative treatments for metropolitan intersections.

   To complement Recommendation 1, it is recommended that further research be undertaken to identify new and innovative treatments for metropolitan intersections, including signalised and non-signalised intersections. This work should also include proposals for the development, implementation and evaluation of trials of innovative measures to create Safe System intersections.

3. In-depth analysis of the factors contributing to run off road crashes and treatments to reduce the incidence of and injury severity.

   This study noted that single vehicle run off road crashes accounted for around one-quarter of serious injury crashes in the metropolitan area and nearly 60% and

70% respectively of serious injury crashes in the regional and remote areas. Further to this, around a third of run off road crashes in the regional and remote areas occurred on curves, with most run off road crashes across all three areas resulting in the collision with an object other than a designated barrier. On the basis of these findings it is recommended that a micro-analysis style project be developed to identify and review roads with a high incidence of run off road events to investigate potential contributing crash and injury factors and appropriate cost-effective countermeasures by location. This project can also draw on the findings from two current C-MARC projects: the epidemiology of single vehicle run off road crashes in metropolitan Perth, and, a review of initiatives to improve curve delineation.

Safe Speeds

4. Identify and audit high crash risk roads in the regional and remote locations to determine the appropriateness of the current speed zone and need for rezoning.

   Though this study was not able to investigate the contribution of excess or inappropriate speeds to serious injury crashes across Western Australia, there was some evidence to support previous research identifying a relationship between crashes in higher speed zones (90km/hour and higher) and serious injury outcomes for the regional and remote area. At issue is whether the roads on which these crashes have occurred are appropriately speed zoned for their condition and level of infrastructure (e.g., sealed roadway and shoulders; edge lining; clear zones; barriers; median to separate vehicles). It is therefore recommended that further research be undertaken to identify and audit high crash risk roads in the regional and remote areas to determine the appropriateness of the posted speed limit and make recommendations where appropriate for a lowering of the speed limit to reduce the risk of crashing and serious injury.

5. Undertake an in-depth investigation of unlicensed driving in the remote areas of Western Australia.

   Drivers involved in serious injury crashes in remote Western Australia were twice as likely as those crashing in regional WA and metropolitan Perth to be unlicensed (i.e., not holding a current, valid licence at the time of the crash). It is therefore recommended that a program of both quantitative and qualitative research be undertaken to address the following issues:

   - the extent of unlicensed driving;
   - persons at risk of unlicensed driving;
   - factors associated with the failure of remote areas residents to obtain and maintain a valid motor vehicle drivers' licence and drive unlicensed; and,
   - a review of the effectiveness of existing systems and programs in remote Western Australia to promote licensure.

   The research should also consider how best to (i) engage remote communities to take responsibility for the problem of unlicensed driving and to reduce the incidence of; (ii) the provision of alternate modes of transport other than private vehicle use, and (iii) more strategic detection and enforcement initiatives and appropriate penalties (i.e., vehicle impounding; wheel clamping;) for unlicensed driving.

6. Undertake an in-depth investigation of the use of alcohol and drink driving in remote and regional Western Australia.

   Around 13% of drivers involved in a serious injury crash tested positive (non-zero) for alcohol; this proportion was greatest in remote Western Australia (23.4%) compared with regional WA (16.5%) and metropolitan Perth (11.2%). Even more concerning was the finding that three-quarters of remote area drivers and 60% of regional area drivers who tested positive recorded a BAC $\geq$ 0.08gm%. Understanding the unique area-specific factors that predispose non-urban area drivers to drink drive and the development of relevant countermeasures is thus warranted. Both quantitative and qualitative methods should be used to investigate

the range of factors associated with the use of alcohol in non-urban areas and compliance/non-compliance with drink-driving legislation, in particular:

- the extent of drink driving;
- persons at risk of drink driving;
- the range of individual, sociocultural and community-wide factors that support or inhibit drink driving;
- access to alcohol and alternative means of transport;
- current detection and enforcement practices and the appropriateness of penalties for non-urban area residents; and,
- how best to reduce the incidence of alcohol impaired driving.

7. Undertake an in-depth investigation of the non-use of seat belts by motor vehicle occupants in remote areas of Western Australia.

   Seat belt use can significantly reduce the risk of serious injury in the event of a crash and yet in this study remote area drivers (inclusive of helmet use by riders-15.6%) and passengers (33.8%) were considerably more likely to be unbelted compared with those involved in crashes in metropolitan Perth and even regional WA. At present there is no contemporary evidence of the prevalence of and risk factors for the non-use of seat belt across Western Australia using observational (as opposed to crash) data. Given the level of non-use identified in this study among remote area motor vehicle occupants there is a need for research using a mix of quantitative (observational data) and qualitative methods to understand:

   - the prevalence of use and non-use of seat belts and other restraints among remote area motor vehicle occupants;
   - persons at risk of being 'unrestrained';
   - the range of individual, vehicle, sociocultural (particularly Indigenous issues) and community-wide factors that support or inhibit appropriate restraint use;
   - current detection and enforcement practices and the appropriateness of penalties for remote area residents; and
   - how best to increase the use of seat belt by drivers and passengers.

8. Detailed examination of the pattern of pedestrian injury crashes in regional and remote Western Australia.

   The majority of pedestrians killed or hospitalised state-wide were involved in crashes in the metropolitan area, though the risk of being fatally injured was greatest for pedestrians involved in crashes in the regional and remote location. This is perhaps because of their greater likelihood of being hit whilst using roads with higher posted speed limits and the lack of facilities for safe walking. Given the higher risk of fatal injury for pedestrians, the is good reason to undertake a detailed examination of the high risk localities in regional and remote Western Australia to determine the circumstances and risk factors for pedestrian crashes so as to develop appropriate and effective counter measures in relation to engineering and road user behaviour initiatives.

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