Investigation of Technologies to Reduce Motorcycle Crashes at Intersections

Final Report

Client:

VicRoads – Road Safety and Network Access

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EXECUTIVE SUMMARY

This report combines Parts One and Two of an investigation into crashes at intersections involving motorcycles (and motor scooters). Part One included interrogation of the VicRoads RCIS database to determine the crashes involving motorcyclists at intersections between 1 January 2003 and 31 December 2007. In addition the Police report for each crash was read to establish additional information about each crash.

Part Two investigated potential infrastructure and technology solutions to improve safety for motorcyclists at intersections, with consideration to the crash patterns investigated and established in Part One.

The suitability of the potential infrastructure and technology solutions for specific intersection types has been considered. Part One of this study highlighted the following most-common motorcycle crash scenarios:

- Cross traffic (DCA 110) at cross intersections
- Right through (DCA 121) at cross intersections
- Right near (DCA 113) at T-intersections
- Right through (DCA 121) at T-intersections
- The proportion of crashes at cross intersections was approximately the same for intersections with and without traffic signal control
- The proportion of crashes at T-intersections was significantly higher at unsignalised intersections than at signalised T-intersections (probably due to the provision of these across the network)

Part Two of the study included a literature review of Australian and overseas literature relating to intelligent transport systems (ITS) applications for motorcycles. This showed there has not been significant research in this area, except in Japan (Honda). The literature review was extended to ITS applications which could be adapted to motorcycles. Much of the ITS literature relates to vehicle-to-vehicle communication applications, whereas the aim of this study was to investigate vehicle-to-infrastructure communication applications. Consultation with Australian and overseas experts in road safety was conducted to investigate research underway and not yet reported. Consultation was also conducted with industry representatives of suppliers for the infrastructure and technology solutions. The combination of the literature review and the consultation has guided the recommendations within this report.

Infrastructure solutions include elements to slow vehicles down to reduce the likelihood of a crash, and the severity of a crash. In addition, infrastructure solutions can include the provision of adequate sightlines at intersections (the MAIDS study[1] showed that half of all motorcycle crashes at intersections were attributed to poor visibility). The solutions may include the provision of roundabouts at intersections, and lower speed environments to encourage lower vehicular speeds. The approaches to roundabouts should be clear of obstructions and have appropriate approach angles. Too high an angle may lead to excessive deceleration on the approach and may lead to rear-end collisions, whilst too low an angle may lead to a motorcycle being hidden from the view of drivers of other vehicles.

The geometry of intersections should maximise sightlines and reduce vehicle speeds. In addition, a smooth braking surface should be provided at intersections, and intersections positioned on straight sections of road. Street furniture, trees and fences should be located to not impede on sightlines on the approach to and within the intersection, and be located a few metres from the edge of the road so they are less likely to be struck by an errant rider.

With regard to intersection control, 26% of all motorcycle intersection crashes occurred at signalised intersections, whilst 65% occurred at unsignalised intersections, and 9% occurred at roundabouts.

At intersections with traffic signal control, the most common crash type was right through (DCA 121). At roundabouts the most common crash type was cross traffic (DCA 110). At unsignalised intersections, the most common crash type was right near (DCA 113) and right through (DCA 121).

The crash scenarios investigated with regard to potential infrastructure or technology solutions to improve rider safety are summarised in Table E1.

[1] *ACEM, "MAIDS In-Depth Investigations of accidents involving powered two wheelers, Final Report 2.0"*, April 2009

Table E1: Infrastructure & Technology Solutions for Motorcycle Crash Types

Motorcycle Crash Type	Infrastructure & Technology Solutions
Right through crashes at traffic signal controlled cross intersections	a) Extend all red phase b) Extend red signal phase on one approach c) Fully control right turns d) Vehicle activated sign (VAS) or Variable message sign (VMS) warning to other drivers of approaching motorcycle
Right through crashes at traffic signal controlled T-intersections	a) Extend all red phase b) Extend red signal phase on one approach c) Fully control right turns d) VAS or VMS warning to other drivers of approaching motorcycle
Right through crashes at unsignalised T-intersections	a) Improve sightlines & reduce vehicle speeds (e.g. construct roundabout) b) VAS or VMS warning to other drivers of approaching motorcycle
Right near crashes at unsignalised T-intersections	a) Improve sightlines & reduce vehicle speeds (e.g. construct roundabout) b) VAS or VMS warning to other drivers of approaching motorcycle
Cross traffic crashes at unsignalised cross intersections	a) Improve sightlines & reduce vehicle speeds (e.g. construct roundabout) b) VAS or VMS warning to other drivers of approaching motorcycle
Cross traffic crashes at roundabouts	a) Improve sightlines & reduce vehicle speeds b) VAS or VMS warning to other drivers of approaching motorcycle

The system requirements for each vehicle detection and classification option were investigated, and the costs associated with the supply and installation of the options, including system integration where required, and the ongoing annual maintenance costs. Estimated BCRs range from less than 1.0 to 14.11 for sites with two motorcycle crashes, but are is dependent on the cost of the solution, the number and severity of motorcycle crashes at the site, and the speed zone.

The recommendation is to trial motorcycle detection at a T-intersection with a high number of motorcycle crashes, where geometric and sightlines improvements cannot be made, and the alternatives listed in Table E1 cannot be provided. In addition to the motorcycle detection, the trial should include the provision of vehicle activated signs on two approaches to warn other drivers of an approaching motorcycle, to reduce the number of right through (DCA 121) and right near (DCA 113) crashes involving other drivers failing to see approaching motorcyclists. Site selection should consider the potential impact of the proposed treatment on other traffic with regard to the Network Operating Plans (although the use of a VAS or VMS to warn drivers of approaching motorcyclists is considered to have a minimal impact on other traffic, whereas a fully controlled right turn could have a significant impact).

A trial conducted at a T-intersection will be more cost effective to implement, as there are fewer approaches. At a cross-intersection, all four approaches may require motorcycle detection and vehicle activated signs, unless there is a trend of crashes on only one or two approaches. Therefore a trial at a T-intersection would be cheaper to install and monitor the effectiveness, safety benefits, and impact on traffic flow than at a cross-intersection. If the trial is found to successfully reduce the number of motorcycle crashes, it could then be introduced at cross-intersections as well as T-intersections.

Due to the high installation and maintenance costs associated with the provision of motorcycle detection and vehicle activated signs, these measures should be the last option, when other alternatives are not possible to achieve.

Investigation of Technologies to Reduce Crashes Involving Motorcyclists at Intersections

Part 1 – Investigation of Motorcycle Crashes

Client:

VicRoads – Road Safety and Network Access

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EXECUTIVE SUMMARY

This report assesses the Police reports of crashes at intersections within Victoria involving motorcyclists over a five year period (between 1 January 2003 and 31 December 2007).

The details of the crashes are analysed and the key factors are discussed with respect to seasonal and time of day variations; road classification; road geometry; issues specific to metropolitan and regional areas; interaction with public transport; typical crash types; behavioural factors; speed zones; intersection geometry and intersection control.

The key issues within each group are discussed and the analysis indicates the most common crash types at all locations in the five year period were Right Through (DCA 121) crashes, Right Near (DCA 113) crashes and Cross Traffic (DCA 110) crashes.

The crashes commonly occurred where the major approach is a primary arterial road with a 60km/h speed zone. The crashes generally occurred during the day on a dry road surface.

The key contributing factor to the crashes was identified to be the driver failing to give way to an approaching motorcyclist before entering the intersection or changing lanes with driver error accounting for over 76% of collisions.

Although motorcycle speed is generally considered to be a key contributing factor to motorcycle collisions, the Police reports specifically indicated the motorcycle speed was a factor in only 0.5% of collisions.

The majority of crashes were found to occur at unsignalised intersections (with Give Way or Stop sign control on the minor approach).

The predominant crash types at unsignalised T-intersections were Right Near (DCA 113) and Right Through (DCA 121) crashes. At unsignalised cross intersections, the predominant crash types were Cross Traffic (DCA 110) and Right Through (DCA 121) crashes.

Motorcyclists were identified to be ‘lane splitting’ during only 4% of the total number of crashes however these primarily occurred during Right Through (DCA 121) crashes at unsignalised intersections. Similarly, motorcyclists were identified legally travelling in the kerbside lane adjacent to queued vehicles during a further 3% of all crashes, and primarily during Right Through (DCA 121) crashes at unsignalised intersections.

The most common crash scenario at traffic signals was identified to be the Right Through (DCA 121) crash type involving a driver turning right at a cross intersection in a 60km/h speed zone during dry, daylight conditions.

The most common crash scenario at roundabouts was identified to be Cross Traffic type (DCA 110 – 116) crashes at cross intersections in a 60km/h speed zone during dry, daylight conditions.

These findings will be used to investigate potential infrastructure and technologies that may be implemented on a trial basis to reduce the risk of crashes involving motorcyclists at intersections.

TABLE OF CONTENTS

1 INTRODUCTION

Trafficworks has been engaged by VicRoads – Road Safety and Network Access to investigate the occurrence of motorcycle (and motor scooter) crashes occurring at intersections.

The Study involves two parts: Part 1 is an analysis of the crash history of motorcyclists at intersections during a five year period. Part 2 investigates infrastructural solutions and technologies that may be implemented to improve safety for motorcyclists at intersections.

The aim of Part 1 is to determine the key contributing factors to crashes involving motorcyclists at intersections. A thorough analysis of the data set has been undertaken to identify the nature and extent of the crashes including examination of:

- Typical conditions for motorcycle crashes including weather and time of day;
- Typical locations for motorcycle crashes with consideration to:
    - Road classification,
    - Road geometry;
- Issues specific to metropolitan and regional areas;
- Interaction with public transport;
- Typical types of crashes;
- Behavioural factors contributing to the crashes;
- Common factors involved in motorcycle crashes with consideration to:
    - Speed zones,
    - Intersection geometry, and
    - Intersection control.

This report presents the findings of Part 1 to be considered as part of the two stage investigation.

2 METHODOLOGY

The five year history of crashes involving motorcycles and motor scooters at intersections in all municipalities of Victoria between 1 January 2003 and 31 December 2007 was sourced from the VicRoads RCIS Database.

The Police report for each crash was analysed to determine the conditions and key contributing factors to each collision which may not have been clear from the RCIS summary. Factors including hook turns, motorcyclist and driver behaviour, and extraneous circumstances were input into a master spreadsheet for use in analysis. In addition, inconsistencies between the Police report and the RCIS summary were addressed to enable clear analysis of the data.

Additional information regarding the road classification and the presence of divided carriageways were sourced for each crash.

Locations where public transport routes operate through the intersection were identified and recorded for each location in metropolitan Melbourne (i.e. bus routes, tram routes and rail level crossings). Public transport vehicles (i.e. buses, trams and trains) directly involved in collisions with motorcycles or motor scooters at intersections were recorded separately.

The initial data set comprised 3,730 crashes which had been coded into RCIS as involving motorcycles and motor scooters at intersections.

The following crash types were excluded from the data set to allow for concentration on multiple vehicle crashes that could be addressed by infrastructural or technical solutions to be investigated in Part 2 of the Study:

- Single vehicle crashes involving a motorcyclist losing control at an intersection;
- Head-on collisions at intersections on bends, as these were typically not related to the intersection, but the bend in the road, or a rider or driver losing control (DCA 120s);
- A small number of crashes involving elderly people on motorised scooters which generally occurred on the footpath;
- Crashes involving pedestrians (DCA 100s);
- Crashes occurring at private driveways (however crashes occurring at commercial driveways e.g. service stations and off-street car park access points were retained);
- On-path crashes into parked vehicles (DCA 160s);
- Off-path crashes on straight sections of road (DCA 170s); and
- Off-path crashes on curves (DCA 180s).

In addition, there were several midblock crashes that had been coded as intersection-type crashes that were removed from the initial data set.

The resulting data set comprised 2,104 crashes for thorough analysis of the determination of key factors contributing to motorcycle and motor scooter crashes at intersections.

3 RESULTS

3.1 Crash Summary

During the five-year period investigated there were 2,104 casualty crashes reported to Police involving motorcycles and motor scooters at intersections.

The overall statistics regarding the crashes identified are shown in this section with more detailed analysis of the typical locations and scenarios discussed in the following sections.

3.1.1 Casualty Crashes by Year

Figure 1 shows the trend of casualty crashes reported by severity for each year and the data for this graph is included in Appendix A Table A1.

Figure 1: Trend of casualty crashes by severity by year

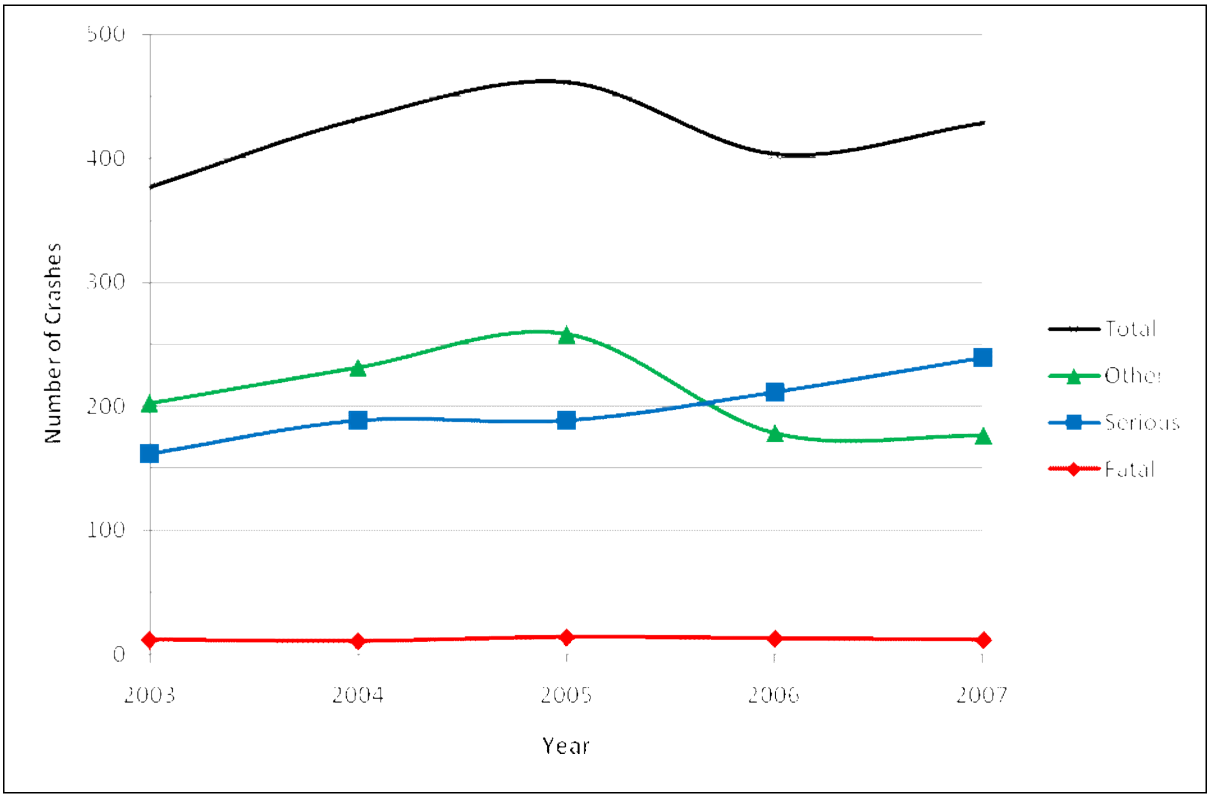


Figure 1 indicates the number of motorcycle and motor scooter crashes increased from 2003 to 2005. The highest total number of motorcycle and motor scooter crashes occurred in 2005 at which time 462 crashes were reported. A significant reduction in crashes followed in 2006 with 404 crashes reported at intersections across the year.

The number of fatalities each year has remained in the same order of magnitude over the five year period (11 – 14 crashes).

The number of serious injury crashes has continually increased each year with the lowest increase being recorded between 2004 and 2005 when the number of serious injury crashes increased by 30 crashes.

Figure 1 shows a notable decrease in other injury crashes from 2005 to 2006 at which time the number of other injury crashes declined by 80 crashes. In the same period, the number of serious injury crashes increased by 23 crashes and there was 1 less fatality recorded. At this time, the system used by Police for reporting serious and other injury crashes was updated and is likely to have resulted in a more accurate assessment of the injury types of crashes.

The number of serious injury crashes increased from 2006 to 2007 with the number of fatalities and other injury crashes remaining approximately constant.

3.1.2 Casualty Crashes by Month

Figure 2 shows the trend of casualty crashes reported by severity for each month of the year (for the five year period). The data for this graph is included in Appendix A Table A2.

Figure 2: Trend of casualty crashes by the month of year

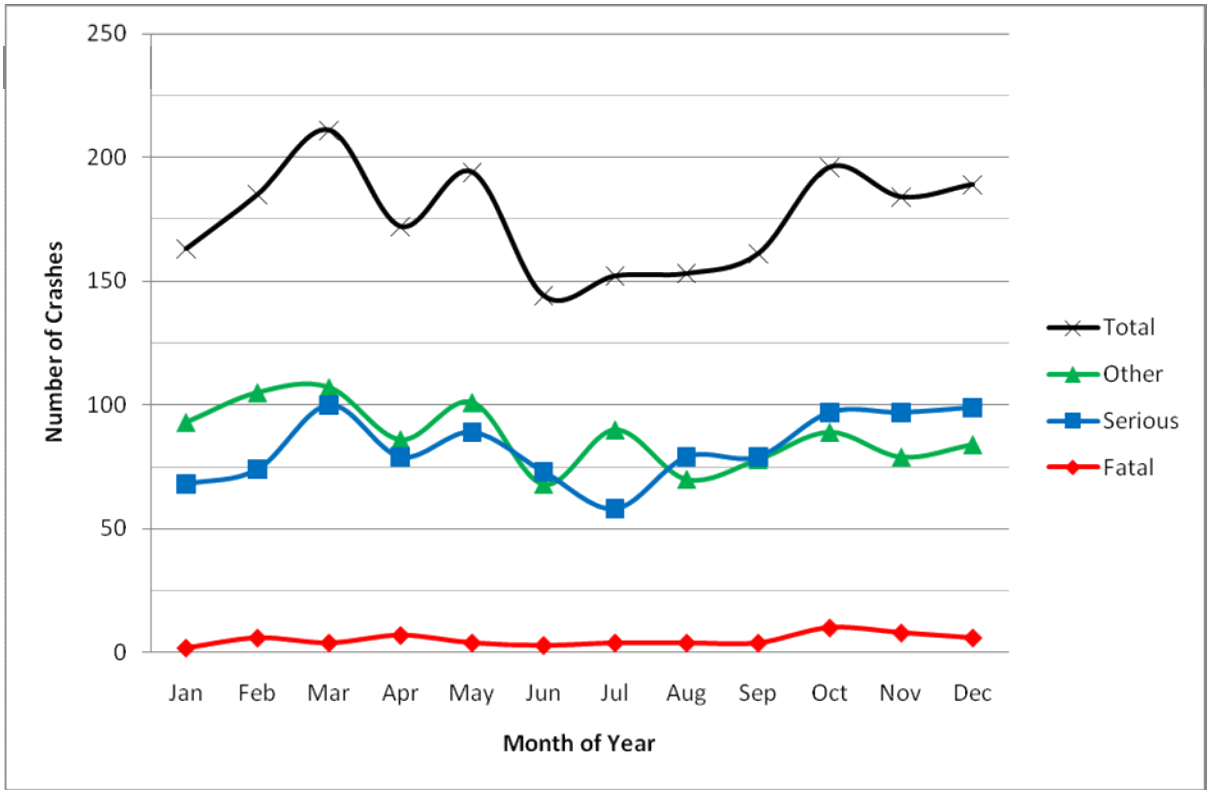


Figure 2 indicates there are generally a higher number of motorcycle crashes reported at intersections between the months of October and May, with between 163 and 211 crashes reported. The months between June and September have less than 162 total crashes reported which may traditionally be due to colder weather with more frequent rain, at which time recreational motorcyclists would be less likely to use their motorcycles.

More specifically, March has the highest incidence of motorcycle crashes, representing 10% of the total intersection collisions. This is likely to be due to a higher exposure of motorcyclists due to favourable weather conditions with consistently warm temperatures and low rainfall.

The months of February, May, October, November and December each have recorded between 184 and 196 crashes over the five year period. These months each represent 9% of the total intersection collisions.

June has the lowest number of motorcycle crashes at intersections with 144 collisions recorded over the five year period. This represents 7% of the total data set.

The number of fatalities is in the same order of magnitude each month and ranges between 2 fatal crashes in January to 10 fatalities recorded in October. The number of fatal crashes in October represents 5% of the total crashes for that month.

The number of serious injury and other injury crashes follow a similar pattern over the months with the notable exception of July. During July, there is a noticeable reduction in the proportion of serious injury crashes and an increase in other injury crashes.

The severity of the crashes is generally lower between January and May with a higher number of other injury crashes compared to serious injury crashes. The other injury crashes represent 50-57% of the total crashes during these months.

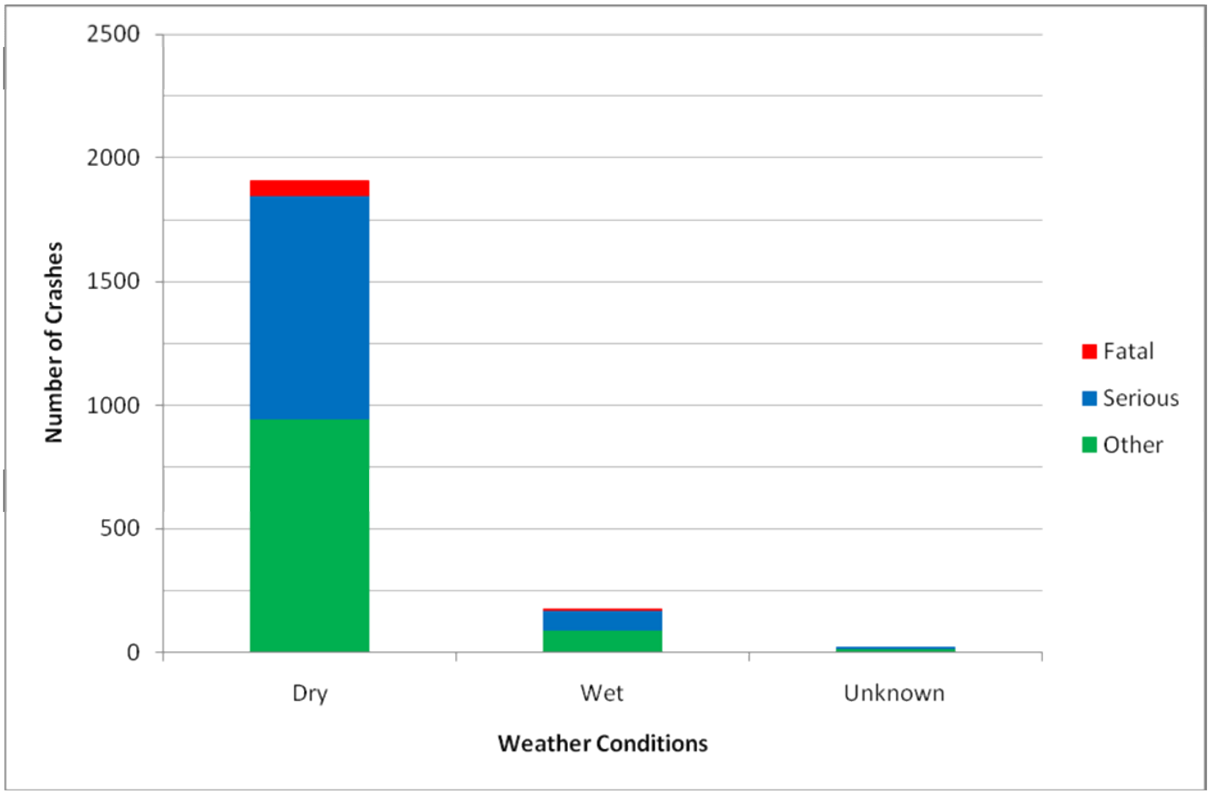
The number of serious injury crashes are higher than the other injury crashes in June and August representing 51% and 52% of the total number of crashes respectively. There have been almost the same number of other injury crashes and serious injury crashes recorded during September (78 crashes and 79 crashes respectively).

A higher number of serious injury crashes compared to other injury crashes have been recorded during the months of October, November and December. During these months the other injury crashes represent 43% to 45% of the total number of crashes.

3.1.3 Casualty Crashes in Varying Weather Conditions

Figure 3 shows the proportion of motorcycle crashes in the three different categories of weather conditions. The source data is included in Appendix A Table A3.

Figure 3: Trend of casualty crashes by weather conditions



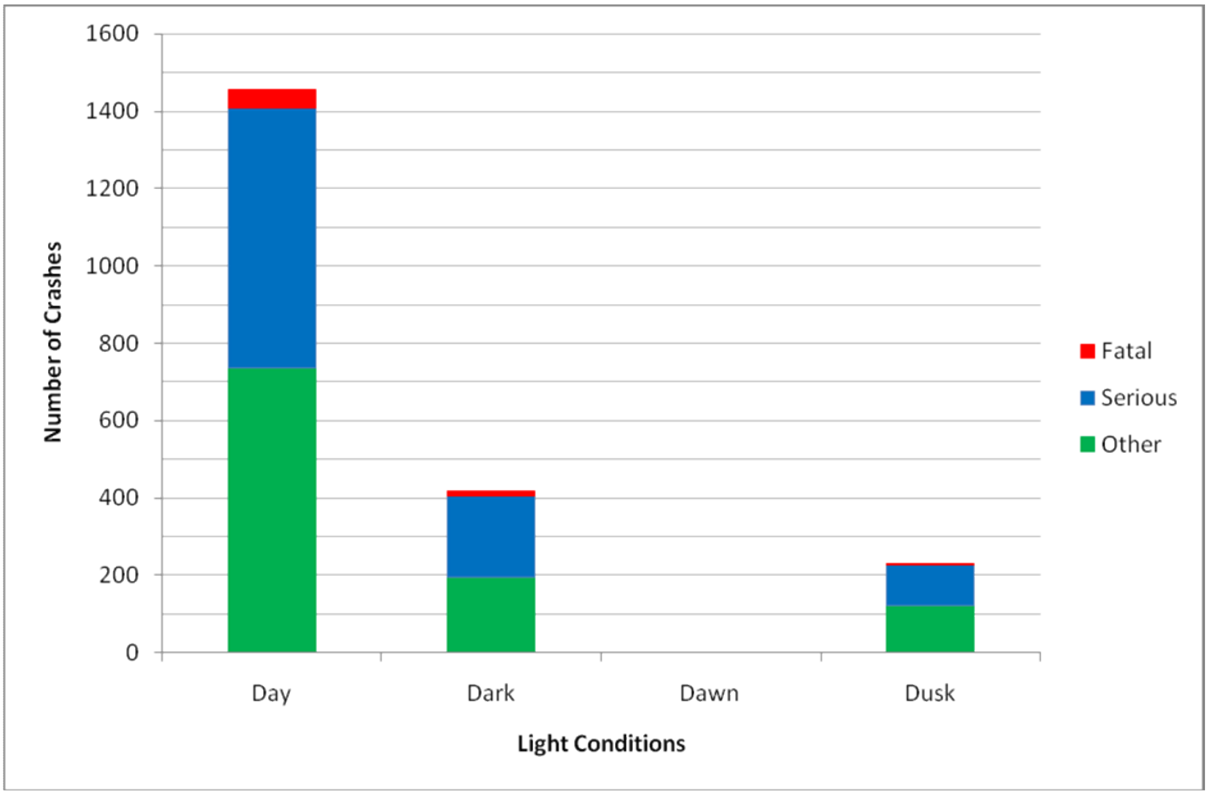
The data indicates 91% of motorcycle and motor scooter crashes occurred in dry conditions. Eight percent of intersection crashes recorded were in wet conditions and 1% of crashes recorded unknown road conditions.

This trend is likely to be due to exposure with motorcyclists generally preferring to ride during dry conditions. Recreational motorcyclists are unlikely to intentionally ride in wet conditions due to the danger of the road surface, rider discomfort and poor visibility.

3.1.4 Casualty Crashes in Varying Light Conditions

Figure 4 shows the proportion of motorcycle crashes in the four different categories of light conditions. The source data is included in Appendix A Table A4.

Figure 4: Trend of casualty crashes by light conditions



The data indicates 69% of motorcycle and motor scooter intersection crashes occurred during daylight hours with 11% during dusk and no crashes recorded during dawn.

The data indicates 20% of crashes occurred during dark conditions at night. Five intersection crashes involved motorcyclists riding in dark conditions without headlights. This equates to 1% of the night-time crashes.

The bias of intersection crashes to daylight conditions is likely to be due to greater numbers of motorcyclists riding during daylight hours, and in particular, recreational riders generally riding during daylight hours only.

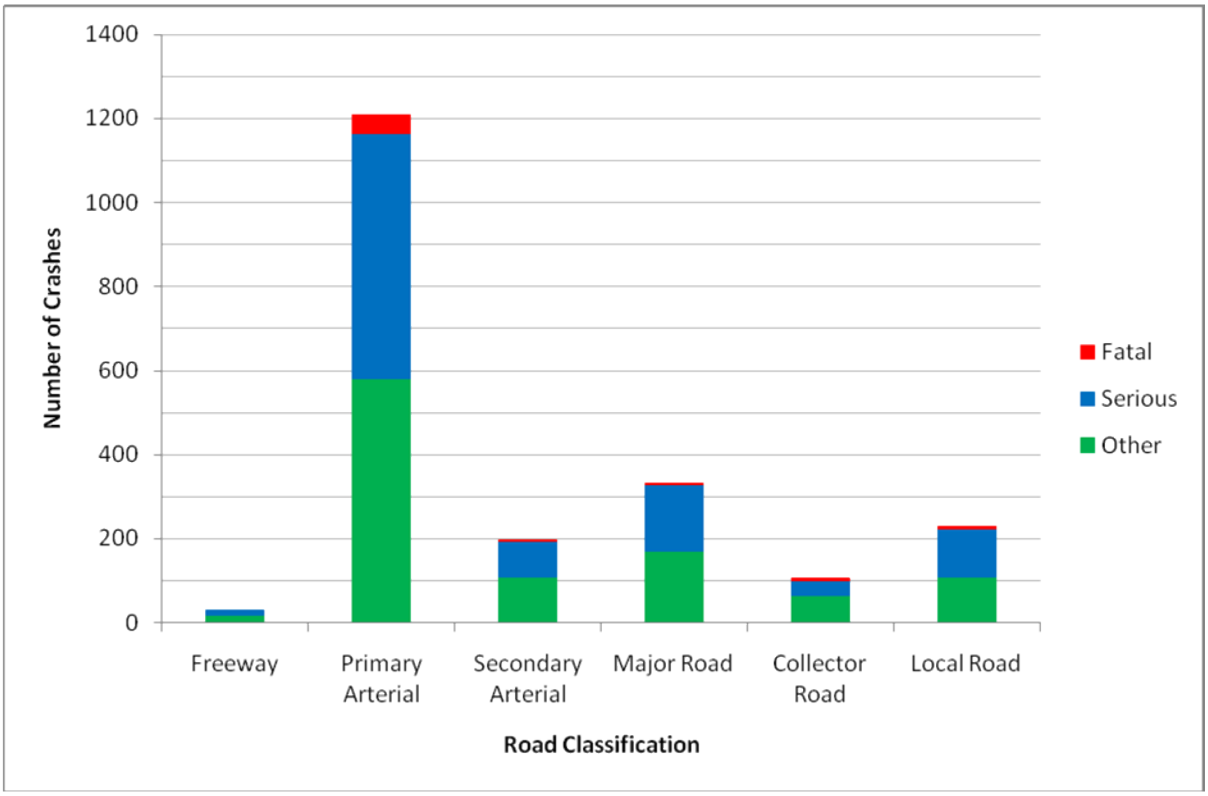
3.2 Road Classification

The data has been assessed for the prevalence of motorcycle crashes at intersections involving the following road classifications as defined in the Melways:

- Freeways
- Primary arterial roads
- Secondary arterial roads
- Major roads
- Collector roads
- Local roads

Figure 5 shows the number of casualty crashes occurring on each road classification during the five year period. The data is also shown in Appendix A Table A5.

Figure 5: Number of casualty crashes by road classification



The data indicates over 68% of motorcycle intersection crashes occurred on the arterial road network, with 58% of the total crashes occurring at intersections involving primary arterial roads.

Major roads represent 16% of the road classifications at motorcycle intersection crash sites with collector roads and local roads making up the remaining 16%.

3.3 Divided Carriageways

The presence of divided carriageways at each motorcycle and motor scooter collision site was determined with reference to the Melways and VicRoads Country Directory. Analysis of the data indicates 47% of crashes occurred at intersections where at least one approach included a central median. The remaining 53% of collisions occurred at intersections where all approaches were undivided carriageways.

Further analysis indicates 3% of the total motorcycle intersection crashes involved vehicles using the median break to turn right or U-turn at the time of the collision. This included 5 fatality crashes, 36 serious injury crashes and 17 other injury crashes.

The majority of the crashes involving vehicles storing in the median break (72% of these crashes) occurred at T-intersections. Approximately a quarter (26%) occurred at cross-intersections and 2% were recorded at Y-intersections.

3.4 Metropolitan and Regional Areas

The sites have been separated into metropolitan and regional areas, with reference to VicRoads regions as follows:

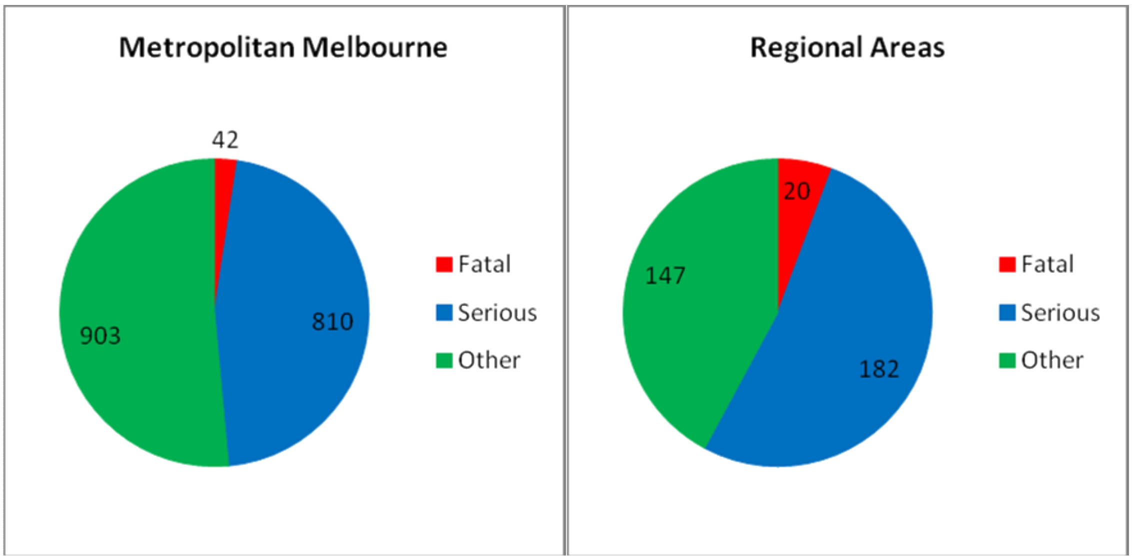
- Metropolitan Areas:
  - VicRoads Metropolitan North West Region
  - VicRoads Metropolitan South East Region
- Regional Areas
  - VicRoads South Western Region
  - VicRoads Western Region
  - VicRoads Northern Region
  - VicRoads North Eastern Region
  - VicRoads Eastern Region

The data indicates 83% of the motorcycle and motor scooter crashes at intersections have occurred in metropolitan areas (VicRoads metropolitan regions), with 17% of crashes occurring in regional Victoria.

It is noted that the regional sites also include major town centres (such as Ballarat and Bendigo) but are located away from metropolitan Melbourne.

Figure 6 shows the number of crashes that have occurred in Metropolitan Melbourne and surrounding regional areas by severity. The data is also shown in Appendix A Table A6.

Figure 6: Number of casualty crashes for metropolitan Melbourne and regional areas



The data indicates crashes in metropolitan Melbourne are generally of lower severity – with other injury crashes representing 51% of motorcycle intersection crashes, serious injury crashes representing 46% and 2% of crashes resulting in a fatality.

Motorcycle crashes at intersections in regional areas comprise a greater proportion of fatal crashes (6%) and serious injury crashes (52%) with other injury crashes representing 42% of the total number of crashes.

This is likely to be due to a higher proportion of crashes on higher speed roads occurring in regional areas compared to metropolitan Melbourne. Crashes occurring in speed zones above 80km/h represent 17% of all motorcycle intersection crashes in regional Victoria compared to 3% of motorcycle crashes in metropolitan Melbourne.

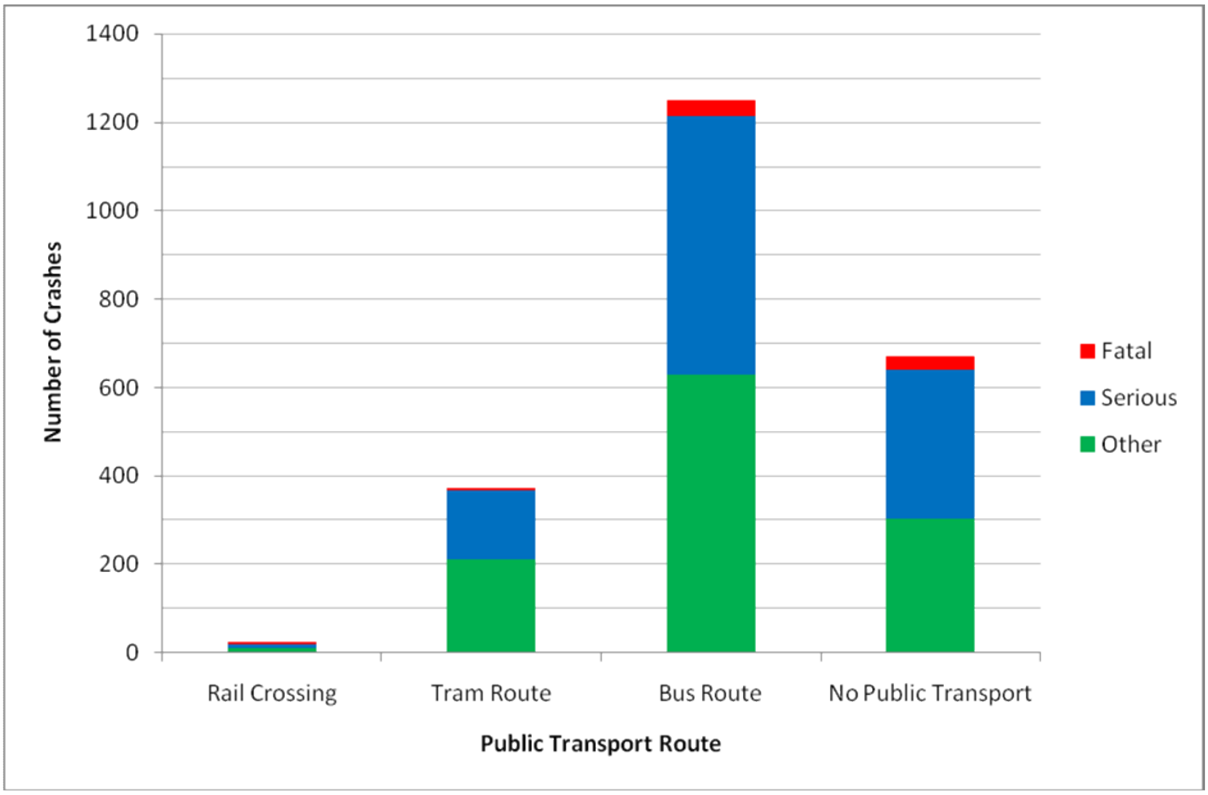
At the other end of the scale, the proportion of crashes in 40km/h and 50km/h speed zones is of the same magnitude in both areas (20% in regional Victoria compared to 18% in metropolitan Melbourne).

In between the two extremes, the proportion of crashes occurring in metropolitan Melbourne within speed zones of 60km/h, 70km/h and 80km/h was 79%, compared to 63% in regional Victoria.

3.5 Public Transport

The occurrence of motorcycle and motor scooter intersection crashes along public transport routes has been analysed. Figure 7 shows the number of crashes occurring by severity along public transport routes, including crashes occurring at intersections combined with rail level crossings. Several crash locations included both tram and bus routes, and bus routes travelling over rail level crossings. Table A7 in Appendix A shows the data including detail of combined routes.

Figure 7: Number of casualty crashes by public transport route



While 78% of motorcycle crashes at intersections have occurred along public transport routes, the majority of these crashes did not involve public transport vehicles.

Analysis of the crashes and the accompanying Police reports indicates 1% of motorcycle and motor scooter intersection crashes either involved a public transport vehicle directly or was influenced by the presence of the vehicle or infrastructure (e.g. tram tracks).

The data indicates the following crashes involved trams or tram infrastructure:

- 2 intersection crashes involved a tram turning at an intersection;
- 2 crashes occurred with motorcyclists traveling in median (separated) tram tracks while vehicles were turning right;
- 1 crash occurred when a driver struck the rear of a motorcyclist slowing for a tram ahead;
- 2 crashes occurred at signalised intersections which involved vehicles turning right into the path of approaching motorcyclists, due to sight distance being restricted by stopped trams at the opposing stopline.

Further to this, the following crashes directly involved buses:

- 2 'Right Through' (DCA 121) type crashes involving buses striking motorcyclists,
- 2 'Right Near' (DCA 113) type crashes involving buses striking motorcyclists;
- 1 crash involved a bus changing lanes into the path of an approaching motorcyclist, and the motorcyclist striking another vehicle whilst swerving to avoid the collision.

Seven of the crashes have occurred at cross-intersections and five crashes at T-intersections generally within speed zones between 40km/h and 60km/h with one crash occurring in a 100km/h speed zone.

Seven of the crashes occurred at signalised intersections and five crashes at Give Way sign or uncontrolled intersections.

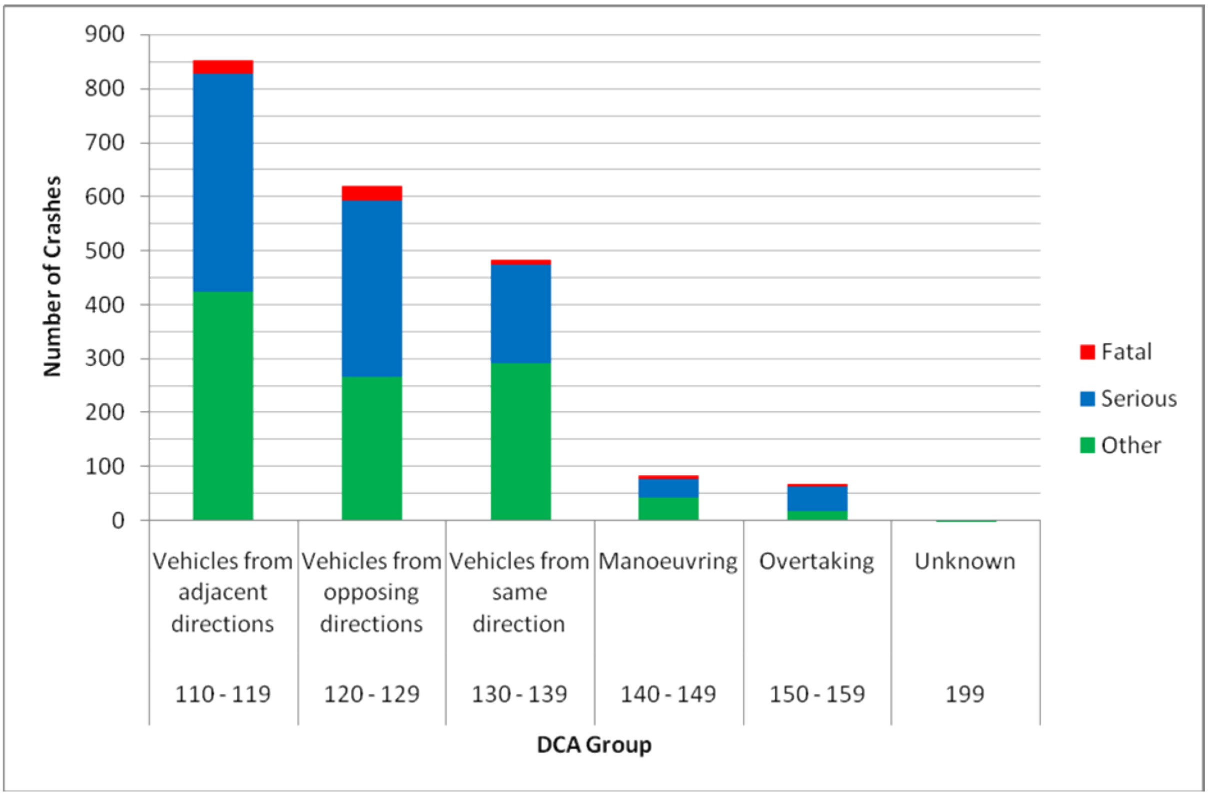
Ten crashes occurred within the metropolitan area while one crash involving a tram was recorded in the City of Greater Bendigo, and one crash involving a bus was recorded in Loddon Shire Council.

3.6 Crash Types

3.6.1 Summary

Each motorcycle intersection crash is coded by DCA (Definition for Classifying Accidents) and has been sorted within the DCA groups of crashes. Figure 8 shows the number of crashes occurring by severity for each DCA group and the source data is shown in Appendix A Table A8.

Figure 8: Number of casualty crashes by DCA group



The data indicates over 40% of crashes are coded as crashes occurring with vehicles approaching from adjacent directions. This includes Cross Traffic crashes, Right Far and Right Near crashes which make up 758 of the 853 crashes within this DCA group.

Vehicles approaching from opposing directions represent 30% of crashes. Right Through crashes represent 603 of the 620 crashes within this DCA group.

Vehicles approaching from the same direction represent 23% of crashes. These crashes include Rear End collisions, Right Rear, Right Turn Side Swipe and Left Turn Side Swipe crashes which represent 351 of the 481 crashes within this DCA group.

Crashes involving vehicles manoeuvring (e.g. U-turn or vehicles emerging from commercial driveways) represent just under 4% of crashes.

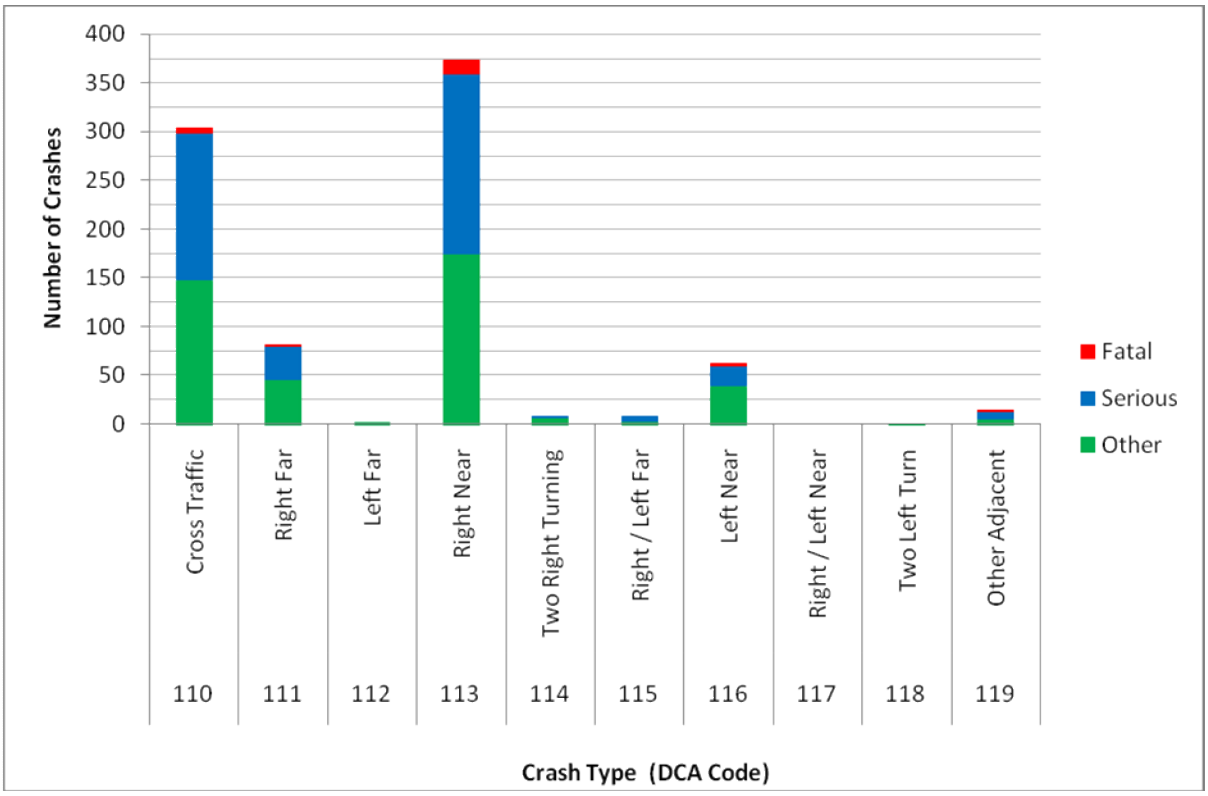
The results indicate overtaking manoeuvres cause 3% of crashes with one other injury crash recorded as an unknown miscellaneous crash.

3.6.2 Vehicles from Adjacent Directions (DCA 110 – 119)

Crashes involving vehicles approaching from adjacent directions (DCA Codes 110 – 119) represent over 40% of all motorcycle crashes at intersections.

Figure 9 shows the number of crashes that have occurred in the five year period for each type of collision involving vehicles approaching from adjacent directions. The source data is included in Appendix A Table A9.

Figure 9: Number of casualty crashes for vehicles approaching from adjacent directions (DCA 110 – 119)



The data indicates the most prevalent type of crashes involving vehicles approaching from adjacent directions are Cross Traffic crashes (DCA 110) where both the motorcyclist and driver are travelling straight (which represent 36% of this crash group), and Right Near crashes (DCA 113) where one party has turned right, across the path of the other person involved in the collision (which represent 44% of this crash group). Both Cross Traffic and Right Near crashes require the participant entering the intersection to assess gaps in oncoming traffic from two directions.

Further analysis indicates the driver's behaviour was the most likely cause of the collision in 83% of the DCA 110 - 119 crashes. Specifically, drivers were identified as failing to give way to motorcyclists in 78% of the DCA 110 – 119 crashes. Police reports included comments from drivers that they didn't see the motorcyclist in 2% of the DCA 110 – 119 collisions. The Police reports included reasons for the motorcyclists not being seen as sight distance being restricted by vehicles in adjacent traffic lanes, leading vehicles turning in front of the motorcyclist, or a horizontal curve in the road alignment.

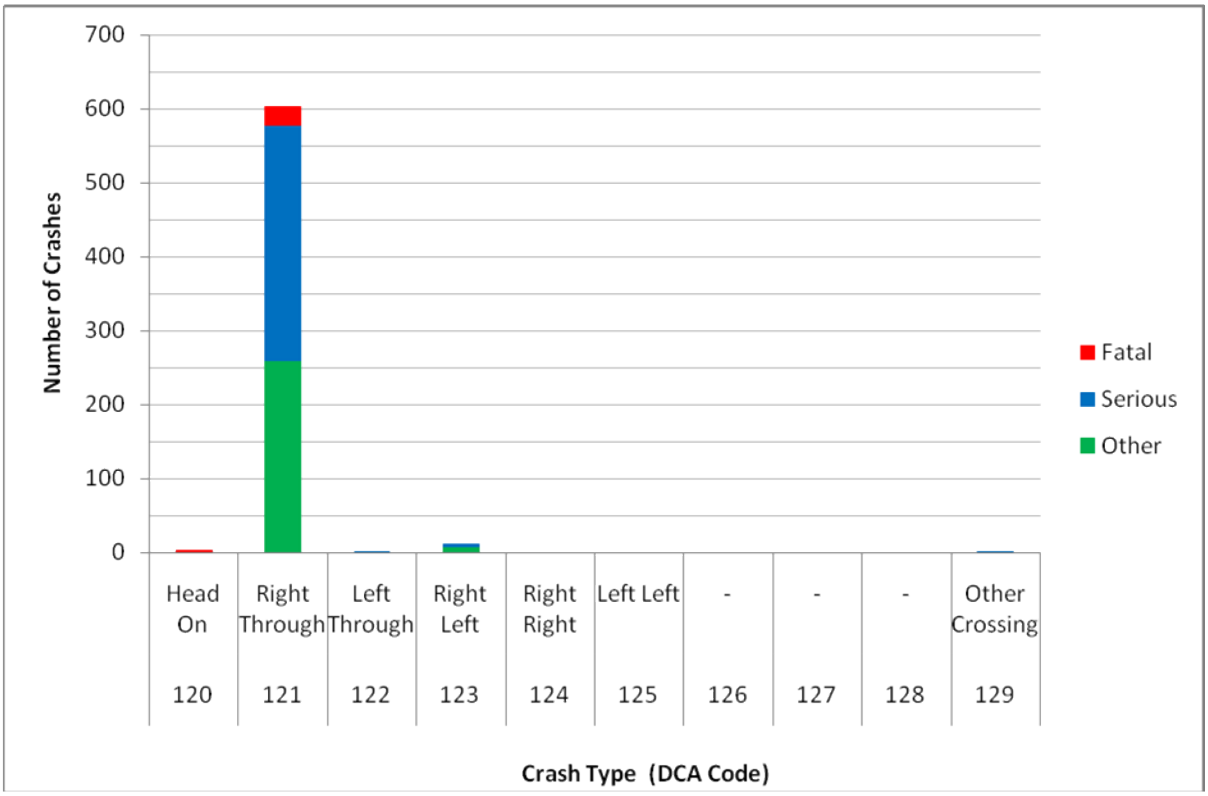
The remaining crashes predominantly included drivers or motorcyclists entering signalised intersections while the traffic signal displayed red, drivers or motorcyclists turning at intersections with turn bans and vehicles blocking traffic lanes while attempting staged crossings.

3.6.3 Vehicles from Opposing Directions (DCA 120 – 129)

Crashes involving vehicles approaching from opposing directions (DCA Codes 120 – 129) represent 30% of all motorcycle crashes at intersections.

Figure 10 shows the number of crashes that have occurred in the five year period for each type of collision involving vehicles approaching from opposing directions. The source data is included in Appendix A Table A10.

Figure 10: Number of casualty crashes for vehicles approaching from opposing directions (DCA 120 – 129)



3.6.3.1 Right Through Crashes

The data indicates 603 Right Through (DCA 121) type casualty crashes have been recorded involving motorcycles and motor scooters at intersections, which represents 97% of this crash group, and 29% of all recorded crashes. The Right Through crashes represent the most common crash type for motorcycle and motor scooter collisions at intersections.

Analysis indicates the majority of Right Through crashes have occurred in 60km/h speed zones (62% of crashes) with additional crashes recorded in each speed zone between 40km/h and 100km/h.

Approximately equal numbers of Right Through crashes have occurred at cross intersections and T-intersections (both representing 49% of Right Through crashes). Approximately half (51%) of the recorded Right Through crashes have been reported at locations with 'No Control' – involving vehicles turning right into a side street in the absence of a roundabout or signalised intersection. Crashes occurring at traffic signals represent 43% of Right Through motorcycle crashes. Over 90% of the Right Through crashes involved the driver of the turning vehicle failing to give way, and often failing to see opposing motorcyclists.

Right Through crashes are over-represented in dark conditions: approximately a quarter of the Right Through crashes (24%) occurred at night. A further 11% were recorded at dusk, and the remaining 65% occurred during daylight. Over 90% of the crashes occurred in dry conditions which is consistent with the general findings for motorcycle crashes at intersections.

The data indicates queued traffic conditions have contributed to 13% of all Right Through crashes. Motorcyclists were reported as moving between the lanes of queued vehicles ('lane splitting') at the time of the collision in 7% of Right Through crashes. Of these crashes involving 'lane splitting', 75% occurred with vehicles turning right into side streets in the absence of a roundabout or traffic signals.

Similarly, motorcyclists travelling in the kerbside traffic lane adjacent to a traffic lane with queued vehicles were found to be present in 6% of Right Through crashes. As per the pattern for motorcyclists 'lane splitting', 79% of the Right Through crashes with motorcyclists in the kerbside lane have occurred at T-intersections with the far majority (85% of crashes) occurring at 'No Control' locations – with vehicles turning right into a side street in the absence of a roundabout or signalised intersection.

Details of the number of traffic lanes within the opposing traffic flow were not specifically included in the analysis and as such, the proportion of Right Through crashes occurring with turning vehicles giving way to vehicles across two or more lanes is unconfirmed.

In some instances, the Police reports specifically indicate drivers did not see the motorcyclist due to vehicles in adjacent lanes, or trams present in the median lane. The Police reports specifically indicated motorcyclist speed may have been a factor in 3 of the casualty crashes, representing 0.5% of the total number of Right Through crashes.

3.6.3.2 Right Left Crashes

The Right Left (DCA 123) type crashes were found to occur more regularly in dusk or dark conditions than average motorcycle intersection crashes, with 27% of crashes occurring at dusk and 27% occurring during the night. Approximately equal numbers of the Right Left (DCA 123) crashes occurred with the driver or motorcyclist turning right, and approximately half of the Right Left crashes occurred at traffic signals. At the signalised sites, some crashes included fully controlled turns for the right turn movement and others were filtered.

3.6.3.3 Head On Crashes

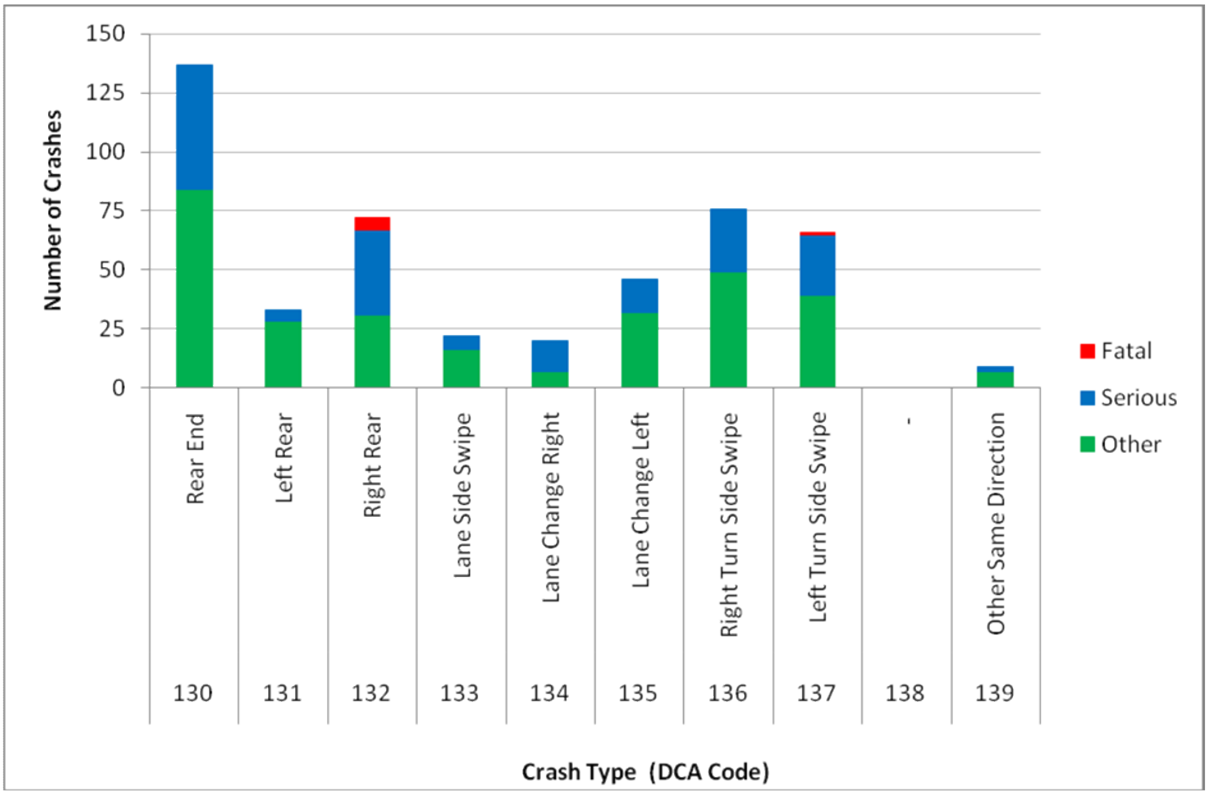
The remaining 3% of crashes comprise four Head On collisions (DCA 120) which occurred on roads with 50km/h and 60km/h speed limits and each involved motorcyclists on the wrong side of the carriageway.

3.6.4 Vehicles from the Same Direction (DCA 130 – 139)

Crashes involving vehicles approaching from the same direction (DCA Codes 130 – 139) represent 23% of all motorcycle crashes at intersections.

Figure 11 shows the number of crashes that have occurred in the five year period for each type of collision involving vehicles approaching from adjacent directions. The source data is included in Appendix A Table A11.

Figure 11: Number of casualty crashes for vehicles approaching from the same direction (DCA 130 – 139)



The data indicates a wide spread of crash types involving the motorcyclist and a driver approaching from the same direction, rather than a specific crash type that can be readily addressed.

The crash data indicates that the severity of these crashes was generally lower than the average motorcycle crashes at intersections, with 61% other injury crashes, 38% serious injury collisions and 1% of crashes resulting in a fatality.

3.6.4.1 Rear End, Left Rear and Right Rear Crashes

The data indicates over 50% of crashes in this group were Rear End (DCA 130), Left Rear (DCA 131) or Right Rear (DCA 132) collisions. These three crash types involved motorcycle rider behaviour causing the collision at 57% of the sites, and driver behaviour identified to cause the remaining 43% of collisions.

Further analysis indicates common crash scenarios were motorcycle riders striking stationary vehicles as the motorcyclist was attempting to stop at the intersection, and motorcyclists were identified as 'following too closely' behind vehicles at a number of crashes. Several crashes also occurred at times where vehicles downstream of the intersection were queued through the intersection, causing vehicles to stop at green signal displays.

Conversely, other common crash scenarios include drivers striking stationary motorcyclists as they were stopping at the intersection, or drivers striking motorcyclists as they were both setting off from the intersection.

The data indicates 11% of the rear crashes (DCA 130, 131 and 132) occurred in wet conditions which is 3% higher than the general trend of motorcycle crashes at intersections. The road surface was dry in 87% of the collisions, and unknown for 2% of the crashes.

Although tram tracks were not reported to contribute to any of the rear end crashes, tram routes were identified at 14% of the sites involving Rear End, Left Rear and Right Rear crashes. This is less than the overall proportion of motorcycle crashes occurring on tram routes which was 18% for all motorcycle crash types.

3.6.4.2 Lane Side Swipe, Lane Change Right & Left, and Right & Left Turn Sideswipe Crashes

The Lane Side Swipe (DCA Code 133), Lane Change Right and Left crashes (DCA Codes 134 and 135), and Right and Left Turn Side Swipe crashes (DCA Codes 136 and 137) represent 48% of crashes in this group.

Analysis of the Police reports indicate similar crashes are coded into the five DCA Codes and as such, these crash types have been considered together for analysis.

The data indicates driver behaviour was prominent in 67% of these crashes, motorcyclist behaviour attributed to 29% of crashes and 5% involved unclear circumstances.

The crashes predominantly occurred in dry weather (at 92% of sites) and wet road conditions contributed to 7% of the crashes which is generally consistent with the overall pattern of motorcycle crashes at intersections.

One third (33%) of this group of crashes occurred along tram routes, which is higher than the overall proportion of motorcycle crashes occurring on tram routes (18% for all motorcycle crash types).

Two crashes (1% of the lane change and side swipe group) involved motorcycles and trams directly colliding. One crash involved a stationary motorcyclist being struck by a tram (while the tram was turning) and the second crash involved a motorcyclist entering a signalised intersection at the start of a phase (with a green signal display) and striking a tram which was completing a turn from the previous signal phase. One further crash occurred involving the driver of a vehicle turning right into a motorcyclist while the motorcyclist was travelling in median tram tracks.

The presence of trams may have contributed to drivers or motorcyclists changing lanes leading to other crashes within this group. The Police reports for this group of crashes, however, did not include any further written description of the presence of trams or the influence of tram tracks during the remaining lane change and side swipe type crashes.

Common crash scenarios included drivers generally changing lanes and striking motorcyclists, or driving into the path of a motorcyclist while specifically changing lanes to turn at an intersection.

Several crashes involved motorcyclists overtaking right-turning vehicles on the right hand side (9% of all lane change and side swipe type crashes), and similarly, motorcyclists overtaking left-turning vehicles on the left hand side of the vehicle (6% of all lane change and side swipe type crashes).

The Police reports identified drivers turning left from the wrong lane (the centre lane, right lane or the central carriageway across a service road) in 8% of the lane change and side swipe type crashes. Similarly, the reports identified drivers turning right from the wrong lane in a further 5% of all lane change and side swipe type crashes.

Several crashes involved both the driver and rider attempting to turn at an intersection with multiple dedicated turn lanes, with either both vehicles turning and colliding or the driver instead continuing straight and striking the motorcyclist. Over 5% of all lane change and side swipe type crashes involved both vehicles initially turning right in this manner, and another 4% involved both vehicles initially turning left.

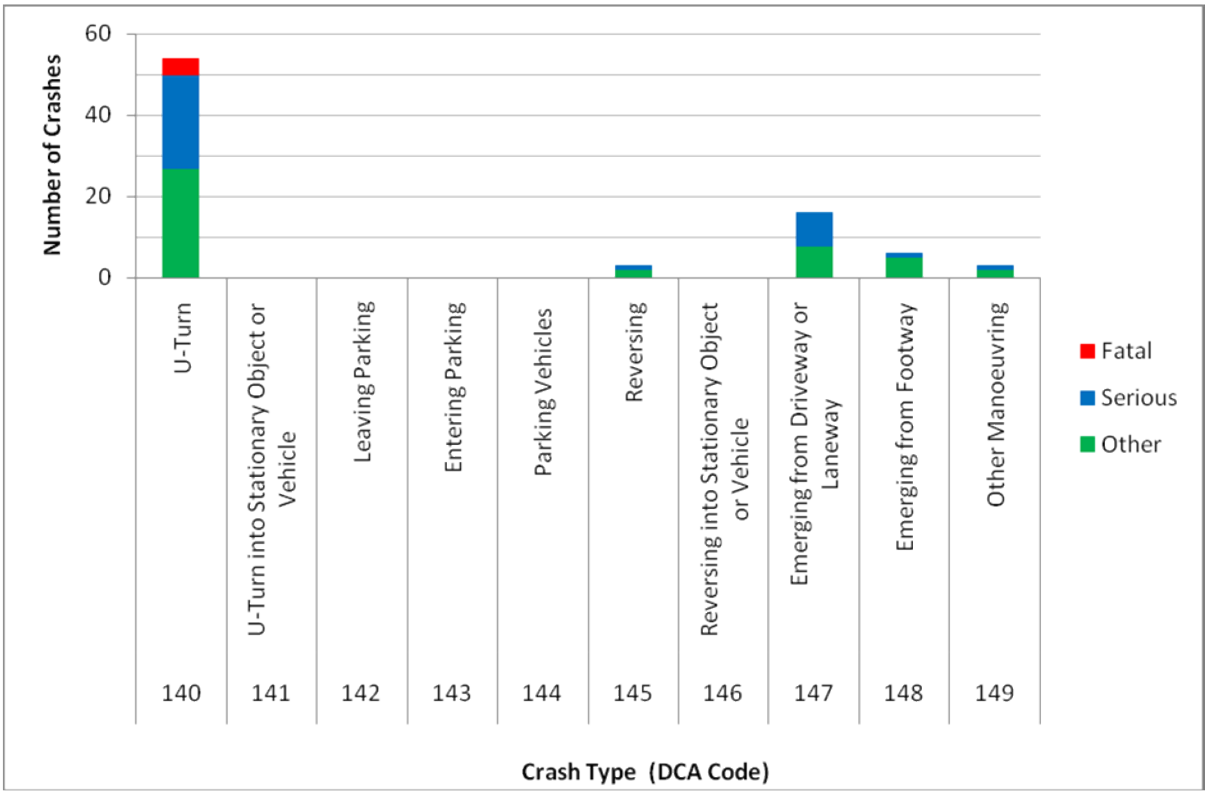
The Police reports identified drivers attempting to change lanes to overtake a vehicle propped to turn right at the intersection in 3% of the lane change and side swipe type crashes.

3.6.5 Vehicles Manoeuvring (DCA 140 – 149)

Crashes involving vehicles manoeuvring (DCA Codes 140 – 149) represent under 4% of the motorcycle crashes at intersections.

Figure 12 shows the number of crashes that have occurred in the five year period for each type of collision involving vehicles manoeuvring. The source data is included in Appendix A Table A12.

Figure 12: Number of casualty crashes for vehicles manoeuvring (DCA 140 – 149)



Motorcycle and vehicle movements involving parking manoeuvres near intersections or involving only one vehicle (e.g. U-turn into stationary object) were removed from the data set for the purpose of this Study.

The data indicates 66% of crashes involving vehicles manoeuvring have occurred due to U-turn movements at intersections. Of the U-turn collisions, 83% involved drivers performing the manoeuvre and failing to give way to opposing motorcyclists.

The 22 collisions involving vehicles emerging from driveways, laneways and footways included vehicles, motorcycles and bicycles exiting commercial driveways (e.g. service stations and off-street car park access points). Analysis indicates the majority of these crashes (68%) involved drivers failing to give way to motorcyclists.

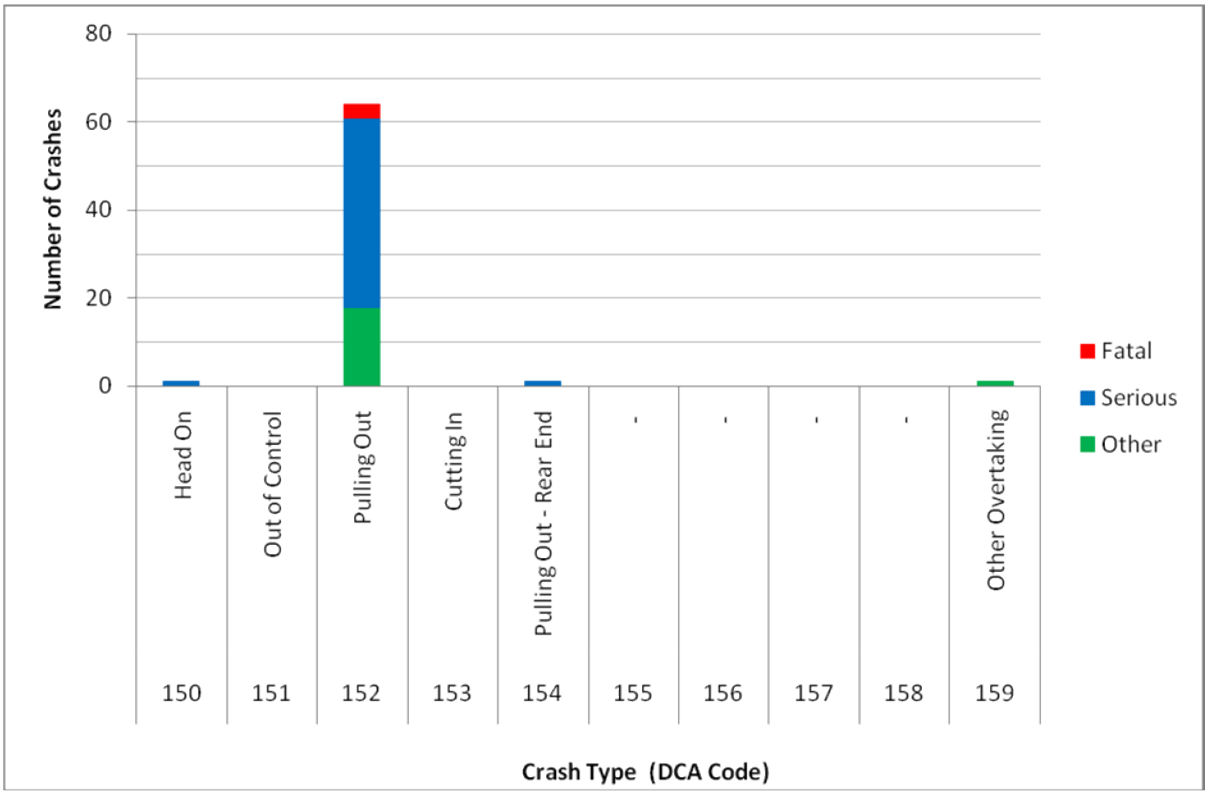
Three crashes were recorded involving drivers reversing from intersection stoplines (not involving parking manoeuvres) and striking approaching motorcyclists.

3.6.6 Vehicles Overtaking (DCA 150 – 159)

Crashes involving vehicles overtaking (DCA Codes 150 – 159) represent 3% of the motorcycle crashes at intersections.

Figure 13 shows the number of crashes that have occurred in the five year period for each type of collision involving vehicles overtaking. The source data is included in Appendix A Table A13.

Figure 13: Number of casualty crashes for vehicles overtaking (DCA 150 – 159)



The data indicates 67 casualty crashes occurred involving overtaking manoeuvres with 28% other injury crashes, 67% serious injury crashes and 4% fatality crashes.

The predominant scenario involved motorcyclists attempting to overtake vehicles (generally on the right hand side) and the vehicles turning right. This scenario was reported at 76% of the crashes within this group (51 casualty crashes). Some of these crashes occurred in queued traffic conditions, with motorcyclists overtaking the queue on the right hand side. Some Police reports indicated drivers turned right without indicating, while other reports indicated that motorcyclists overtook vehicles illegally across double centrelines.

One instance was recorded of a driver attempting to overtake a motorcyclist as it was turning, and another collision involved a right-turning vehicle striking a motorcyclist who was (legally) overtaking another vehicle.

The weather conditions involved with these crashes were generally dry (97% of collisions) and 79% of crashes occurred during daylight conditions, 13% in dark conditions and 8% at dusk. This indicates a higher proportion of these type of crashes occurred in clear daylight conditions compared to the overall trend for motorcycle crashes at intersections.

3.7 Driver and Rider Behaviour

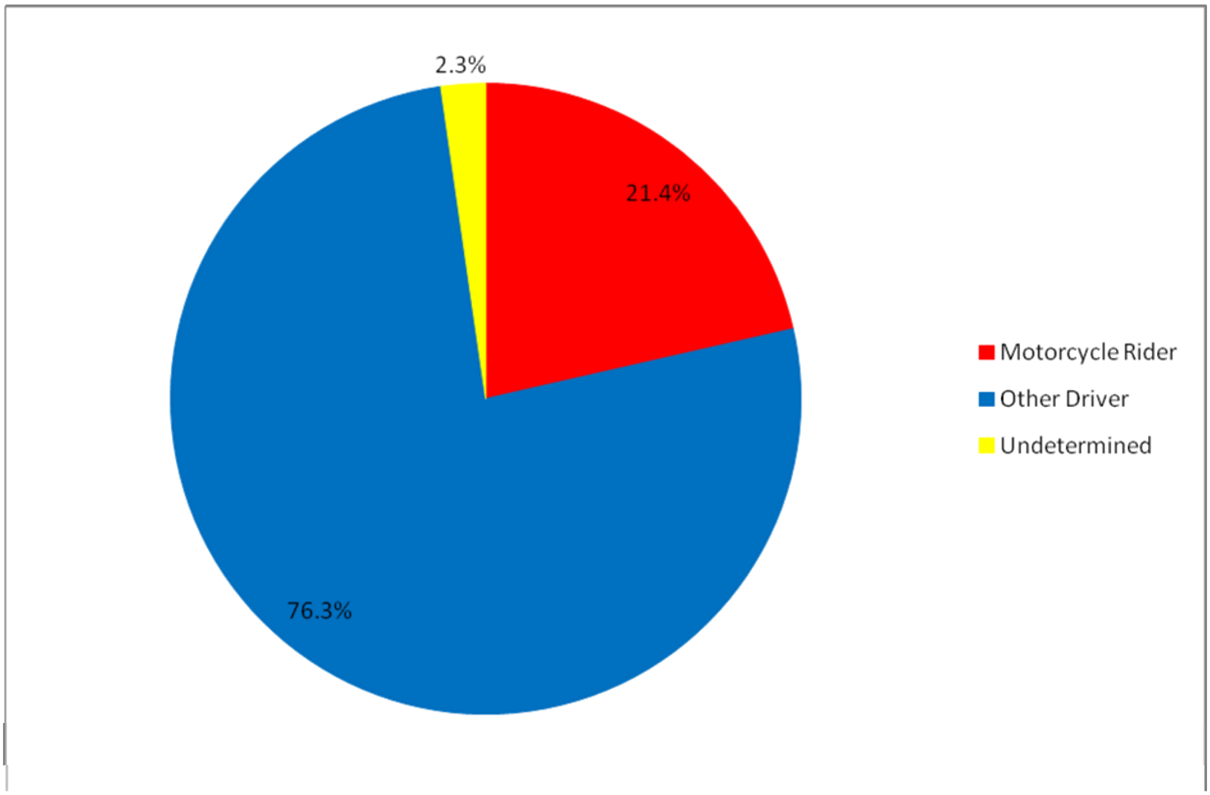
3.7.1 Summary

The Police reports provided a range of detail regarding the conditions leading up to the crash and the behaviour of the motorcyclist and the other driver involved in each collision.

Each crash has been analysed to determine if it was clear whether rider error or driver error was the predominant factor in the collision. For some crashes, both the motorcycle rider and driver performed illegal manoeuvres or otherwise contributed to the collision. In these instances, and at locations where the Police reports were unclear as to the reasons for the collision, the crashes were identified as the result of 'Undetermined' behaviour.

Figure 14 shows the proportion of crashes occurring due to motorcycle rider and driver behaviour with the data included in Appendix A Table A14.

Figure 14: Number of casualty crashes by behaviour



The data indicates that 76% of crashes involving motorcycles and motor scooters at intersection have occurred as a result of driver error. This includes drivers failing to identify motorcycles approaching from an opposing direction (drivers 'not seeing' motorcycle riders) and changing lanes into motorcyclists.

Conversely, 21% of crashes have occurred due to motorcycle rider error. This includes motorcycle riders overtaking vehicles on the right that are performing right turn manoeuvres, and similarly motorcycle riders overtaking vehicles on the left as they are performing left turn manoeuvres. Other crashes involved motorcyclists failing to give way to approaching vehicles and motorcyclists entering signalised intersections facing a red signal lantern.

The conditions surrounding approximately 2% of collisions were unclear to determine whether the behaviour of one person contributed to the crash moreso than the other driver or rider. This includes crashes where the Police descriptions are very brief, and also signalised locations where the traffic signals were out of order or both the motorcycle rider and the driver have performed illegal manoeuvres simultaneously.

It is noted that there was no indication within any of the Police reports to the presence of alcohol or drugs affecting the driver or the motorcyclist at the time of the crash.

3.7.2 Drivers 'Not Seeing' Motorcyclists

Police reports included specific driver accounts of 'not seeing' approaching motorcyclists at 1% of the motorcycle and motor scooter intersection crashes. It is likely that a larger proportion of crashes involved drivers failing to recognise motorcyclists and this was not specifically detailed within the Police reports.

The descriptions of these crashes included motorcyclists being 'hidden' by adjacent vehicles which were generally trucks or four wheel drives. One crash included a description of an adjacent tram restricting visibility to the motorcyclist and a further crash was attributed to sun glare.

Nearly two thirds (59%) of these driver accounts were recorded at Right Through (DCA 121) crashes, and a further third (32%) at Right Near (DCA 113) crashes. Further driver accounts of 'not seeing' a motorcyclist were included at Cross Traffic (DCA 110) and Pulling Out (DCA 152) crashes.

Almost a third (32%) of these crashes occurred in dark (night) conditions, and almost a quarter (23%) occurred in wet weather.

Two thirds occurred in 60km/h speed zones and 91% of crashes occurred at 'No Control', Give Way sign or Stop sign controlled intersections.

3.7.3 General Motorcyclist Behaviour

Police reports included specific accounts of motorcyclist behaviour at 1% of the motorcycle and motor scooter intersection crashes.

The most common descriptions included motorcyclists travelling 'too fast' (48% of driver accounts) and motorcyclists travelling 'too close' (24% of accounts).

In addition, motorcyclists were reported to be 'hooning' and travelling 'up on the back wheel' at 8% of crashes with descriptions of motorcyclist behaviour.

Motorcyclists were identified to be riding without lights at night, without a helmet, or with an unclean helmet visor that restricted visibility in 20% of the crashes that included a description of motorcyclist behaviour. These three elements correlate to 0.2% of all motorcycle crashes reported at intersections.

3.7.4 Motorcyclist Behaviour in Congested Conditions

The data indicates queued traffic conditions have contributed to 6% of all crashes involving motorcyclists at intersections.

Motorcyclists were reported as moving between the lanes of queued vehicles ('lane splitting') at the time of the collision in 4% of the total number of crashes. 'Lane splitting' is no longer permitted however the crashes investigated within this Study occurred prior to the introduction of this rule. The most common crash scenarios were Right Through type crashes involving a vehicle turning right into a side street without giving way to an approaching motorcyclist, and Right Near crashes involving vehicles turning right out of side streets into the path of approaching motorcyclists.

Similarly, motorcyclists travelling (legally) in the kerbside traffic lane adjacent to a traffic lane with queued vehicles were found to be present in 3% of all crashes at intersections involving motorcyclists. As per the pattern for motorcyclists 'lane splitting', most crashes were Right Through crashes with some Right Left crashes occurring with the motorcyclist turning left at the intersection from the kerbside lane at the time of the crash.

In some instances, the Police reports specifically indicated drivers did not see the motorcyclist due to vehicles in adjacent lanes, or trams present in the median lane.

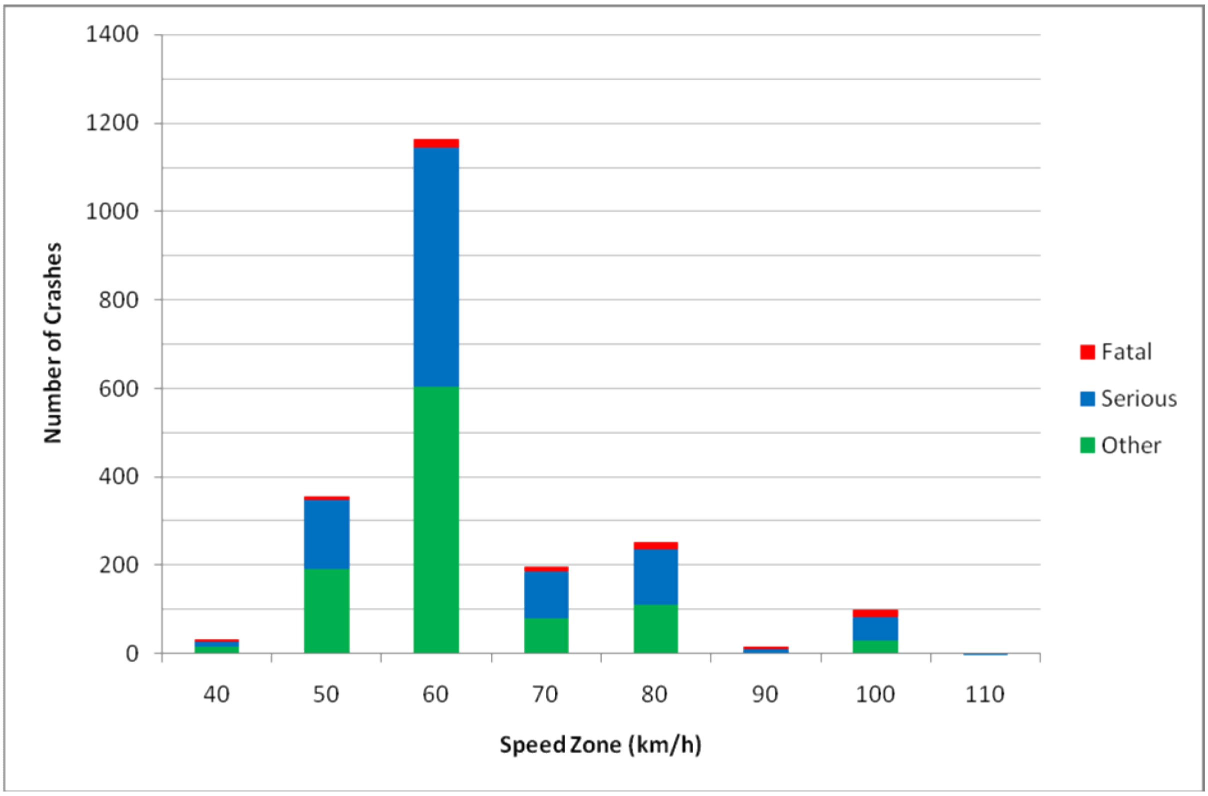
Collisions recorded in queued traffic conditions were found to occur in dry weather (90% of crashes) during daylight (78% of crashes) in 60km/h speed zones (65% of crashes). Over 70% of the crashes occurred in the absence of a roundabout or traffic signals, with 75% occurring at T-intersections.

3.8 Speed Zones

3.8.1 Summary

The applicable speed limit at each intersection has been determined and Figure 15 shows the number of casualty crashes occurring within each speed zone during the five year period. The data is also shown in Appendix A Table A15.

Figure 15: Number of casualty crashes by speed zone



The data indicates over 50% of the motorcycle and motor scooter crashes recorded at intersections have occurred in 60km/h speed zones. Crashes in 50km/h local road speed zones represent 17% of crashes with less than 2% of intersection crashes occurring in 40km/h speed zones.

Twelve percent of crashes were recorded in 80km/h speed zones and less than 10% occurred in 70km/h speed zones. The number of crashes occurring in 90km/h speed zones represent less than 1% of crashes.

Under 5% of crashes have occurred in 100km/h speed zones and above (1 serious injury crash was recorded in a 110km/h speed zone).

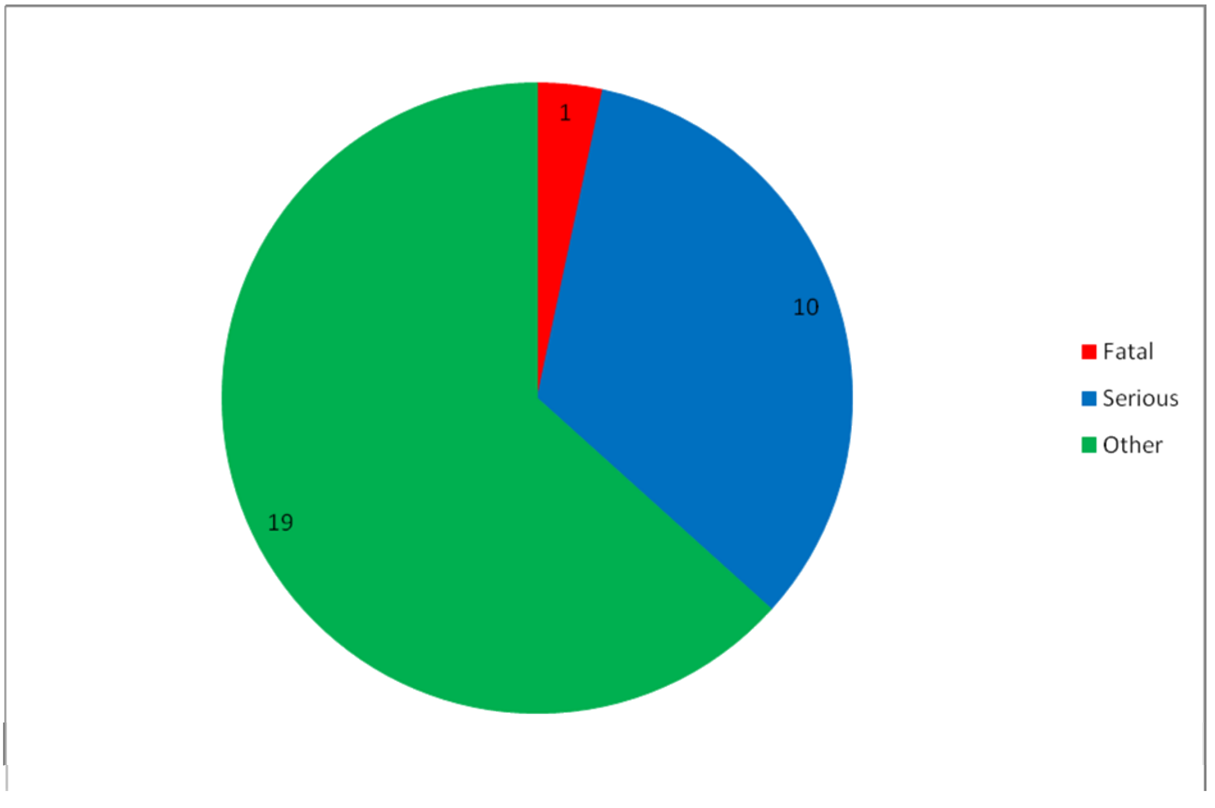
The issues specific to each speed zone are discussed in the following sections.

3.8.2 Speed Zone – 40km/h

There have been 30 crashes recorded in 40km/h speed zones involving motorcyclists at intersections, generally with a lower severity than the average for motorcycle intersection crashes.

Figure 16 shows the severity of crashes in 40km/h speed zones with the data included in Appendix A Table A16.

Figure 16: Number of crashes by severity in 40km/h speed zones



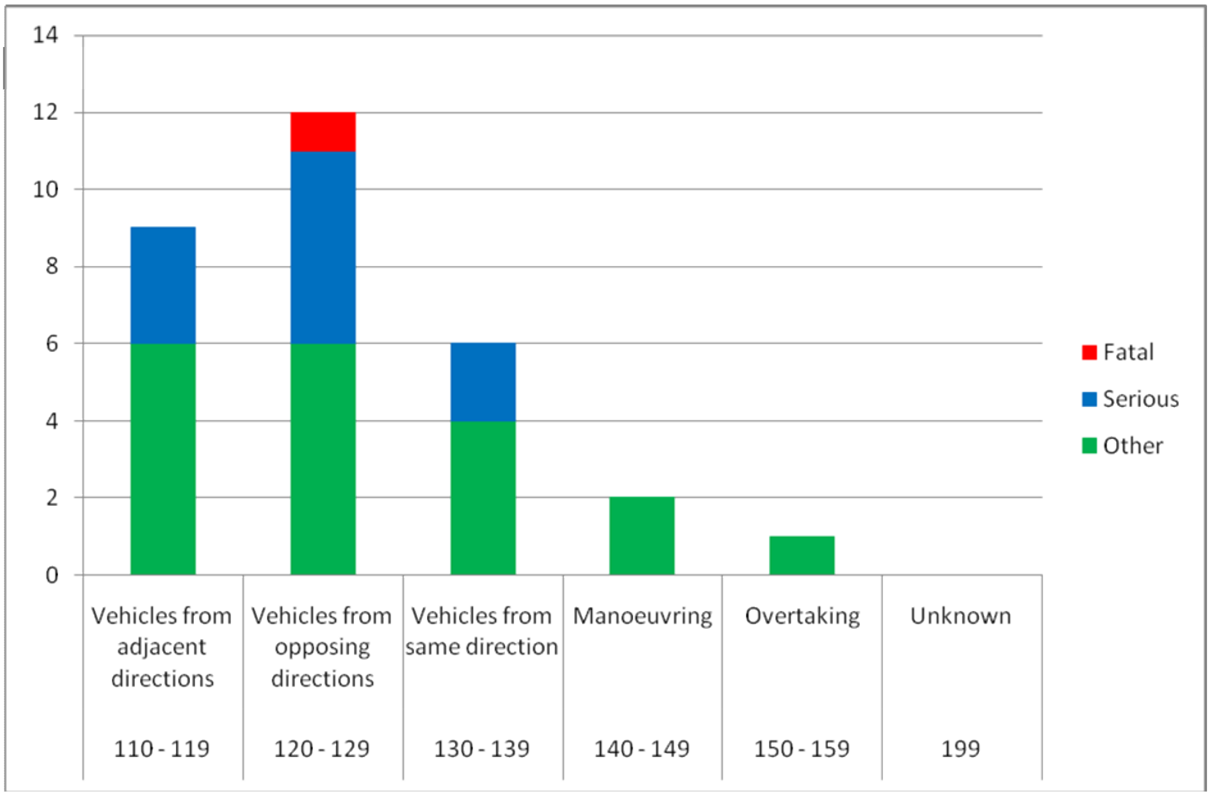
The other injury crashes represent 63% of crashes in this speed zone, with 33% serious injury crashes and 3% (1 crash) involving a fatality.

Over 93% of crashes in 40km/h speed zones were recorded in metropolitan Melbourne.

Just over half of the crashes in 40km/h speed zones have occurred at T-intersections, with 47% occurring at cross intersections. Seventy percent of crashes occurred in the absence of roundabout or traffic signal control (with over 13% occurring at traffic signals).

Figure 17 shows the types of crashes that occurred in 40km/h speed zones. The data is also presented in Appendix A Table A17.

Figure 17: Crash types present in 40km/h speed zones



The most common types of crashes occurring in this speed zone were Right Through (DCA 121) crashes representing 40% of crashes in 40km/h speed zones. Right Near (DCA 113) and Cross Traffic (DCA 110) crashes represent a further 27% of crashes together.

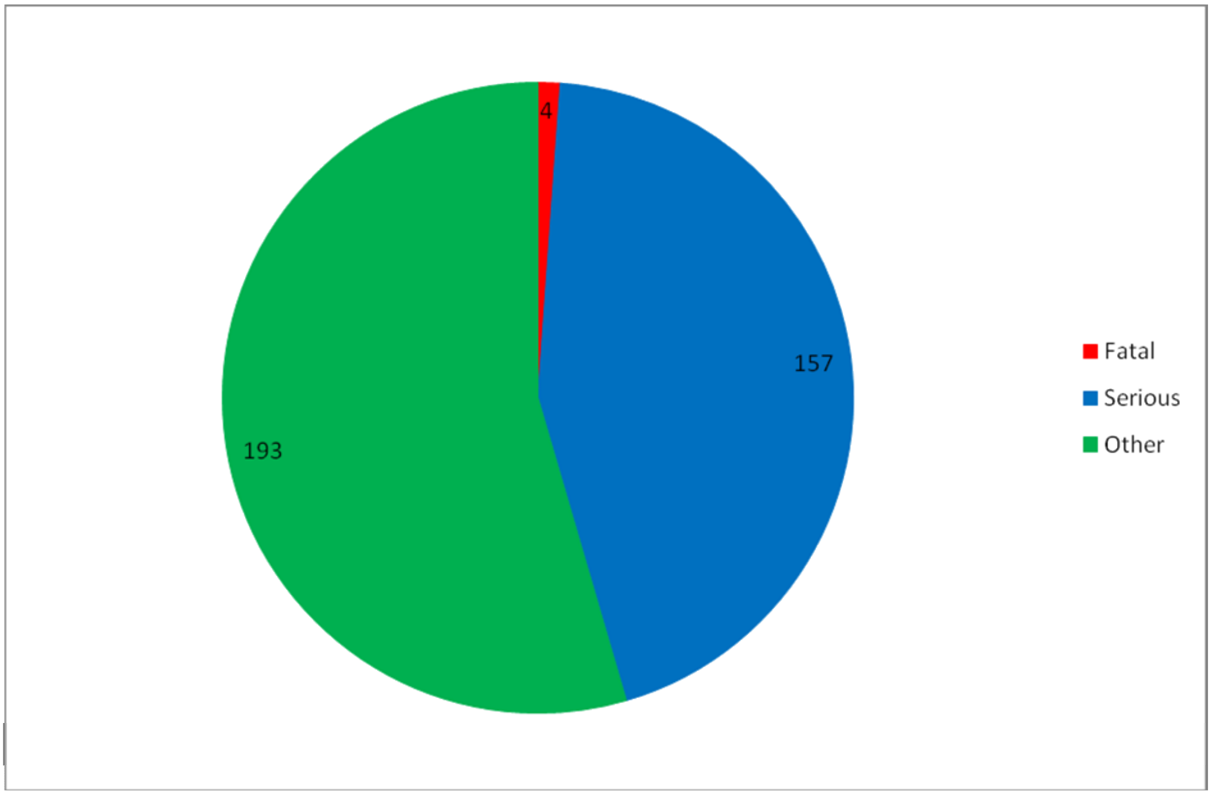
Over 75% of crashes have been recorded during the day with 87% in dry conditions. Over 80% of crashes in this speed zone involved driver error as the main factor, including drivers failing to see opposing motorcyclists. Some crashes included motorcyclists 'lane splitting' or travelling in the kerbside lane adjacent to queued vehicles.

3.8.3 Speed Zone – 50km/h

There have been 354 crashes recorded in 50km/h speed zones involving motorcyclists at intersections.

Figure 18 shows the severity of crashes in 50km/h speed zones with the data included in Appendix A Table A18.

Figure 18: Number of crashes by severity in 50km/h speed zones

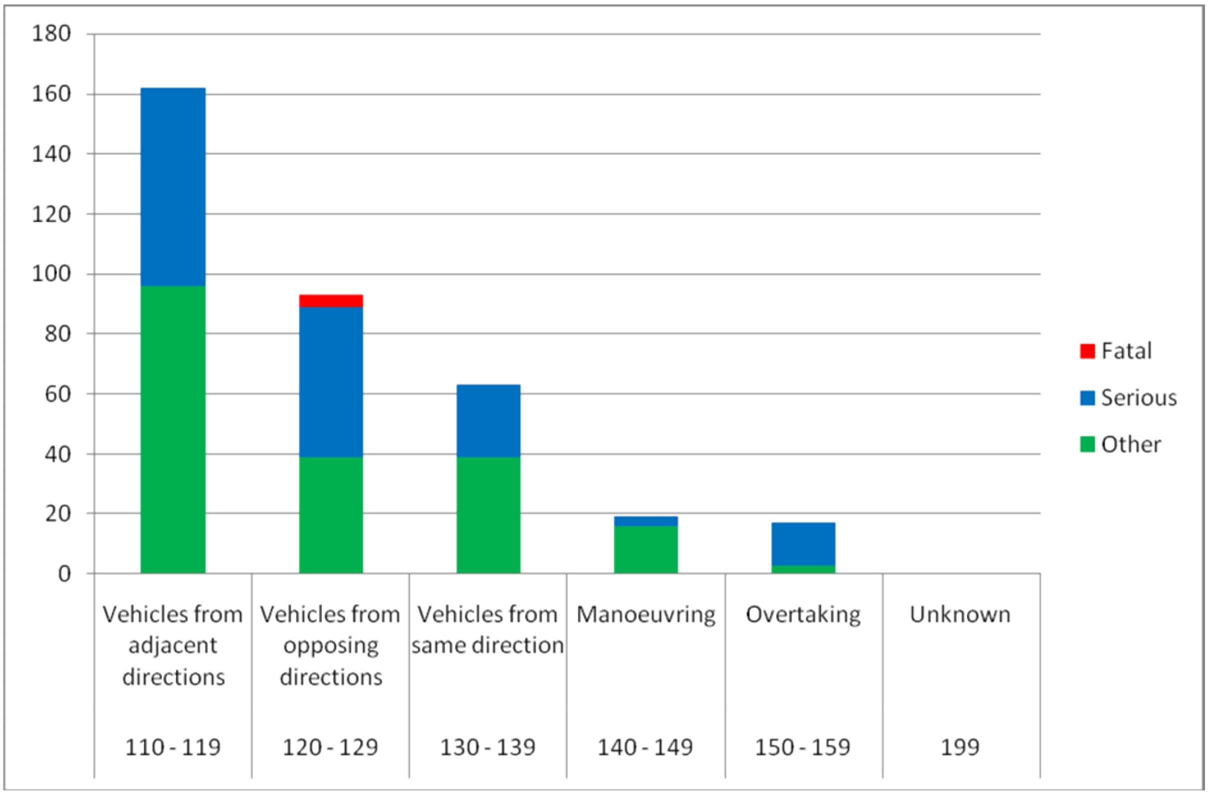


The other injury crashes represent 55% of crashes in this speed zone, with 44% serious injury crashes and 1% involving a fatality. Over 81% of crashes were recorded in metropolitan Melbourne.

The crashes in 50km/h speed zones are more likely to occur at cross intersections (54% of crashes) with T-intersections representing 44% of collisions. Over 40% of crashes occurred in the absence of roundabout or traffic signal control with a further 24% specifically recorded at Give Way sign or Stop sign control. Traffic signals were present (and operational) at 24% of collisions and over 10% of crashes in 50km/h speed zones occurred at roundabouts.

Figure 19 shows the crash types that occurred in 50km/h speed zones. The data is also presented in Appendix A Table 19.

Figure 19: Crash types present in 50km/h speed zones



The most common types of crashes occurring in this speed zone were Right Through (DCA 121) and Cross Traffic (DCA 110) crashes together representing 49% of crashes. A further 15% of crashes were Right Near (DCA 113) type crashes and 5% were Pulling Out (DCA 152) type crashes. Half of the Pulling Out type crashes involved motorcyclists overtaking vehicles as they were turning right.

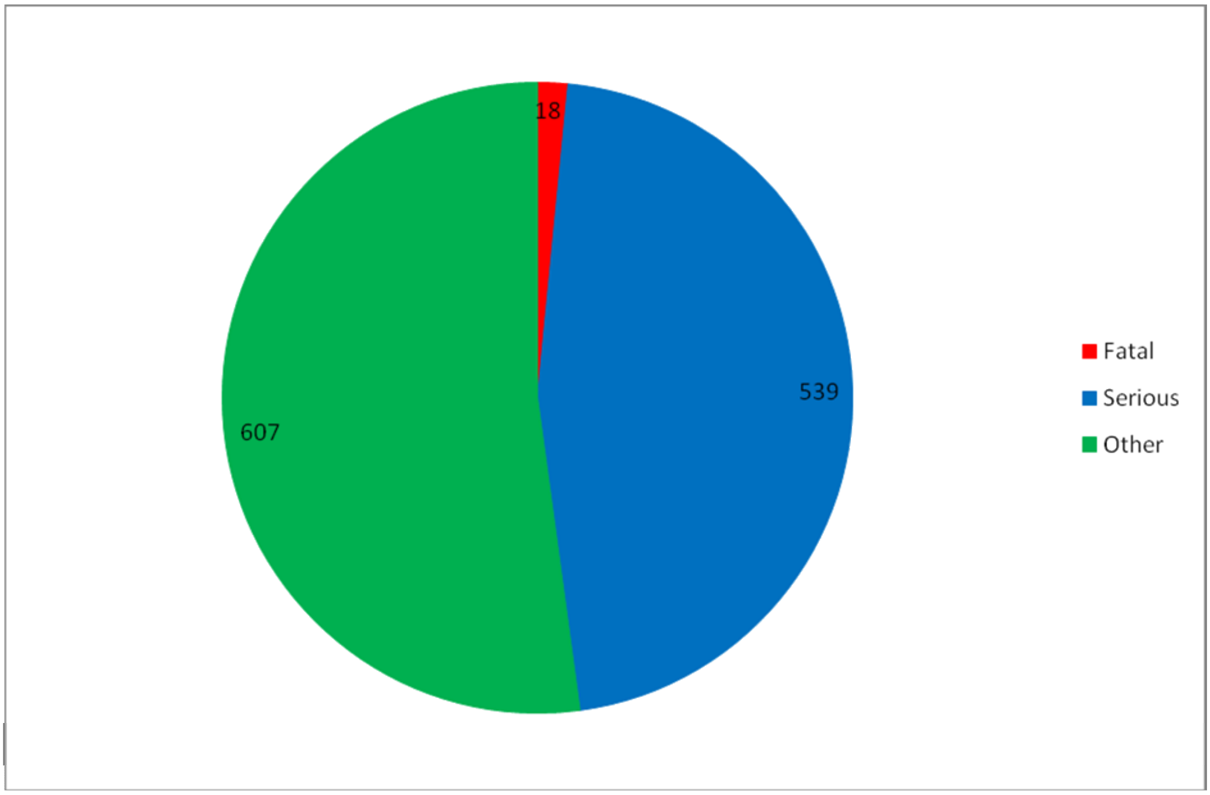
Over 70% of crashes have been recorded during the day with 90% occurring in dry conditions. Over 76% of crashes in this speed zone involved driver error as the main factor, including drivers failing to see opposing motorcyclists.

3.8.4 Speed Zone – 60km/h

There have been 1,164 crashes recorded in 60km/h speed zones involving motorcyclists at intersections.

Figure 20 shows the severity of crashes in 60km/h speed zones with the data included in Appendix A Table A20.

Figure 20: Number of crashes by severity in 60km/h speed zones

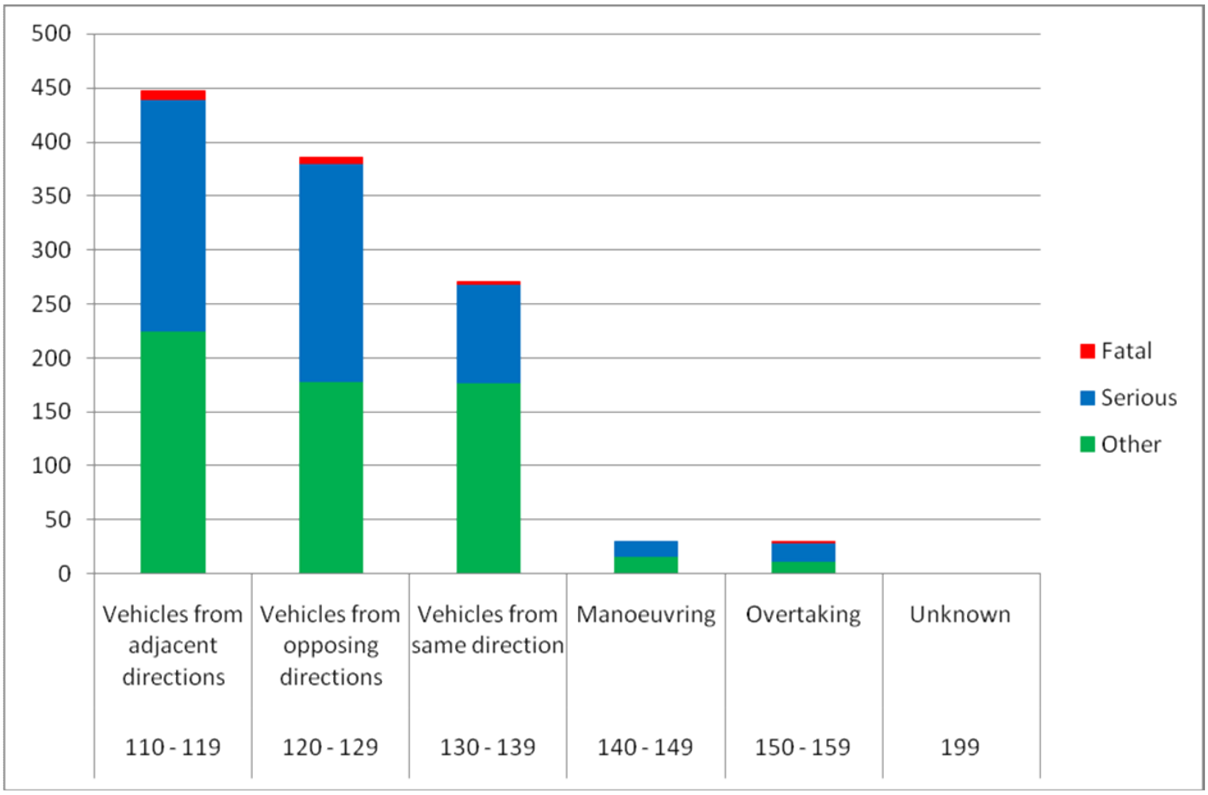


The other injury crashes represent 52% of crashes in this speed zone, with 46% serious injury crashes and 2% (18 crashes) involving a fatality. Over 85% of crashes were recorded in metropolitan Melbourne.

Just over half of the crashes in 60km/h speed zones occurred at T-intersections, with 45% occurring at cross intersections. Over 40% of crashes occurred in the absence of roundabout or traffic signal control with a further 10% specifically recorded at Give Way sign or Stop sign control. Over 28% occurred at traffic signals with 8% of crashes in 60km/h speed zones occurring at roundabouts.

Figure 21 shows the types of crashes that occurred in 60km/h speed zones. The data is also presented in Appendix A Table A21.

Figure 21: Crash types present in 60km/h speed zones



The most common types of crashes occurring in this speed zone were Right Through (DCA 121) type crashes representing 32% of crashes in 60km/h speed zones. Right Near (DCA 113) and Cross Traffic (DCA 110) crashes together represent a further 31% of crashes in 60km/h speed zones.

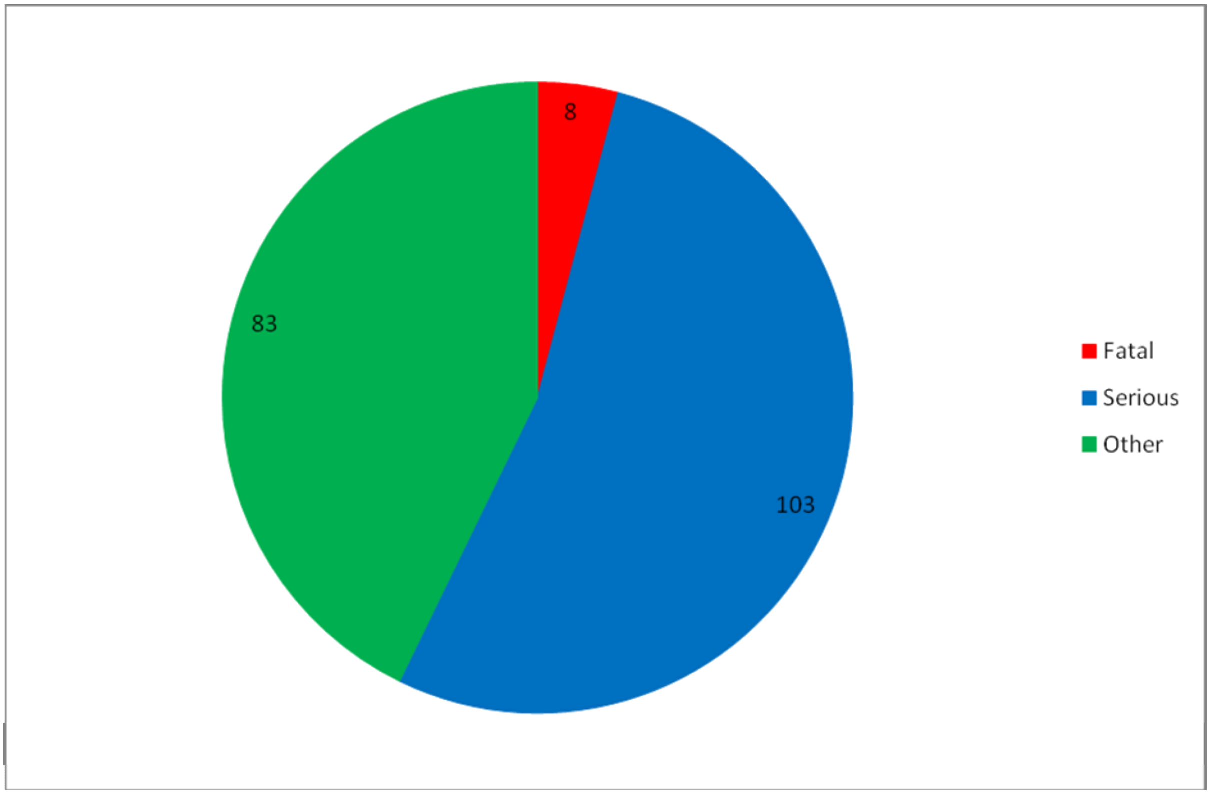
Over 68% of crashes were recorded during the day with 91% in dry conditions. Over 76% of crashes in this speed zone involved driver error as the main factor, including drivers failing to see opposing motorcyclists. Approximately 6% of crashes in this speed zone involved motorcyclists 'lane splitting' or travelling in the kerbside lane adjacent to queued vehicles.

3.8.5 Speed Zone – 70km/h

There have been 194 crashes recorded in 70km/h speed zones involving motorcyclists at intersections.

Figure 22 shows the severity of crashes in 70km/h speed zones with the data included in Appendix A Table A22.

Figure 22: Number of crashes by severity in 70km/h speed zones

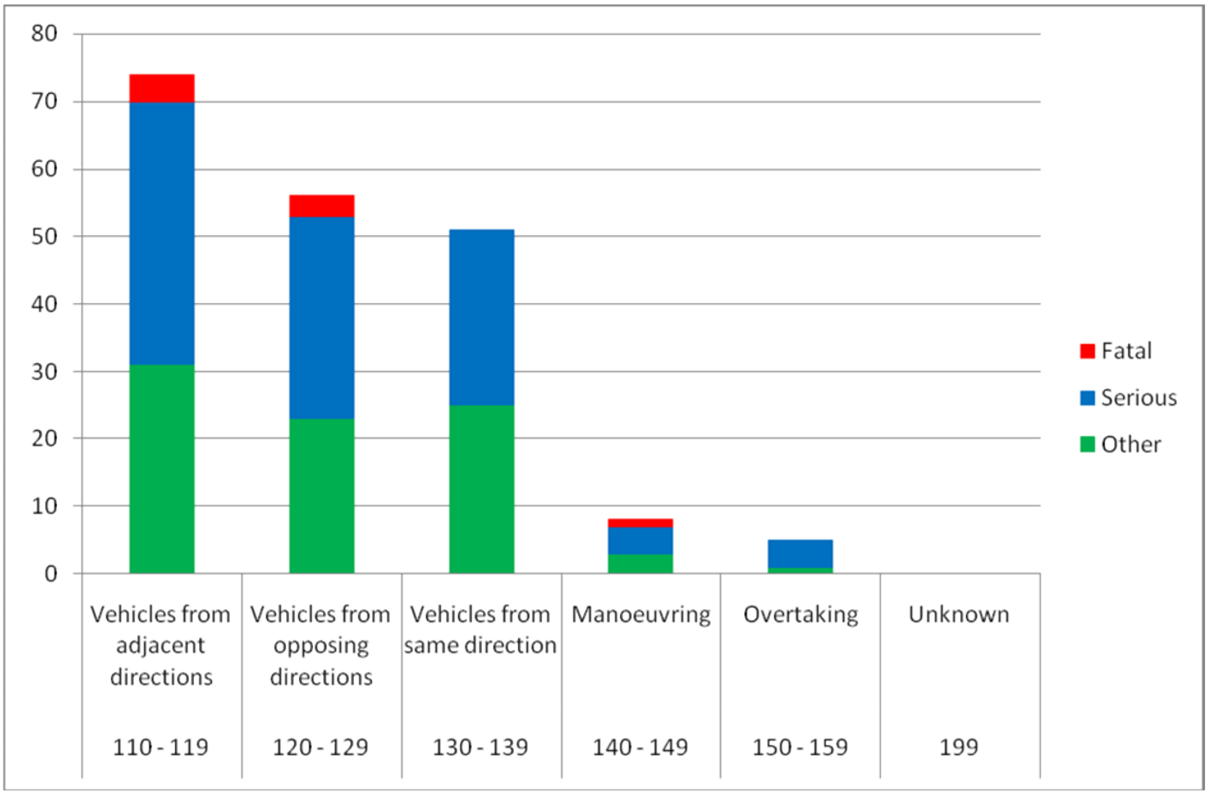


The other injury crashes represent 43% of crashes in this speed zone, with 53% serious injury crashes and 4% involving a fatality. Over 86% of crashes were recorded in metropolitan Melbourne.

Just over half of the crashes in 70km/h speed zones occurred at T-intersections, with 39% occurring at cross intersections. Over 40% of crashes occurred in the absence of roundabout or traffic signal control with a further 21% specifically recorded at Give Way sign or Stop sign control. Over 27% have occurred at traffic signals with 9% of crashes in 70km/h speed zones occurring at roundabouts.

Figure 23 shows the crash types that occurred in 70km/h speed zones. The data is also presented in Appendix A Table 23.

Figure 23: Crash types present in 70km/h speed zones



The most common types of crashes occurring in this speed zone were Right Through (DCA 121) type crashes representing 28% of crashes in 70km/h speed zones. Right Near (DCA 113) and Cross Traffic (DCA 110) crashes represent a further 31% of crashes together. An additional 12% of crashes were Rear End (DCA 130) crashes at which two thirds involved motorcyclist error.

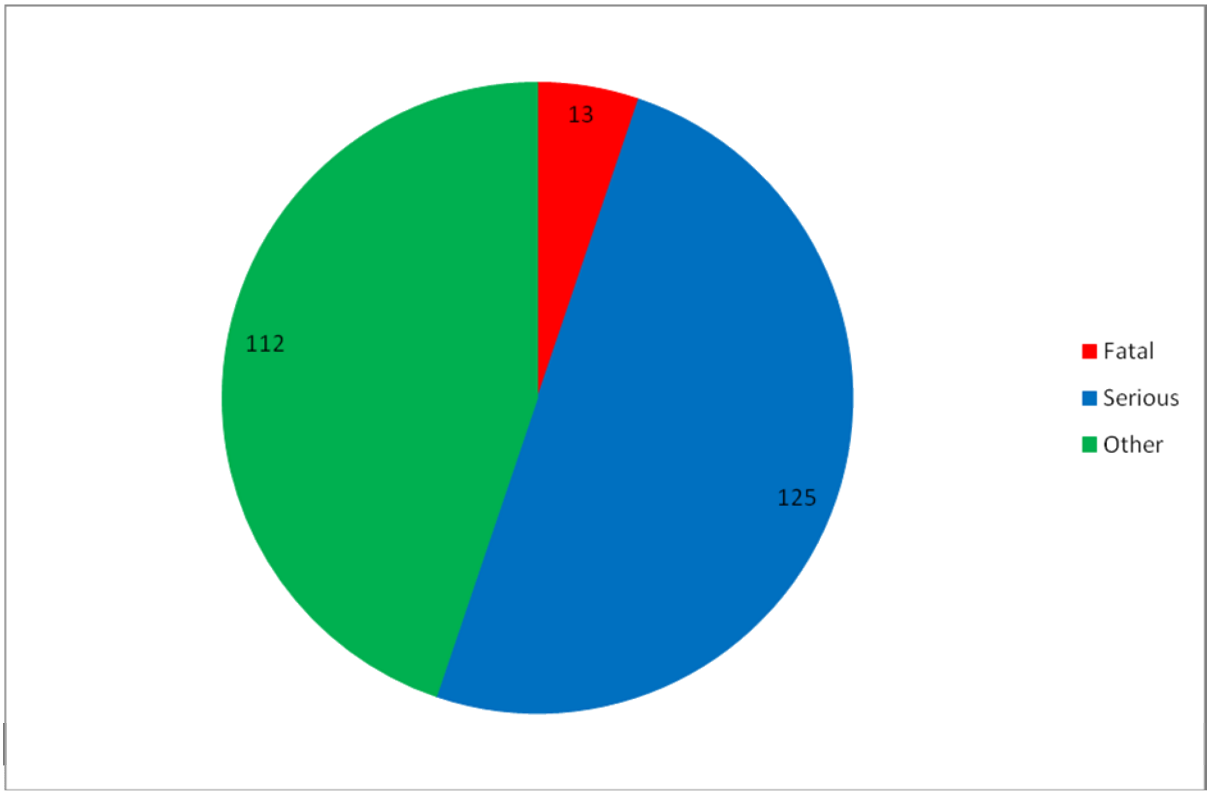
Over 70% of crashes have been recorded during the day with 89% in dry conditions. Over 75% of crashes in this speed zone involved driver error as the main factor, including drivers failing to see opposing motorcyclists. Approximately 8% of crashes in this speed zone involved motorcyclists 'lane splitting' or travelling in the kerbside lane adjacent to queued vehicles.

3.8.6 Speed Zone – 80km/h

There have been 250 crashes recorded in 80km/h speed zones involving motorcyclists at intersections.

Figure 24 shows the severity of crashes in 80km/h speed zones with the data included in Appendix A Table A24.

Figure 24: Number of crashes by severity in 80km/h speed zones

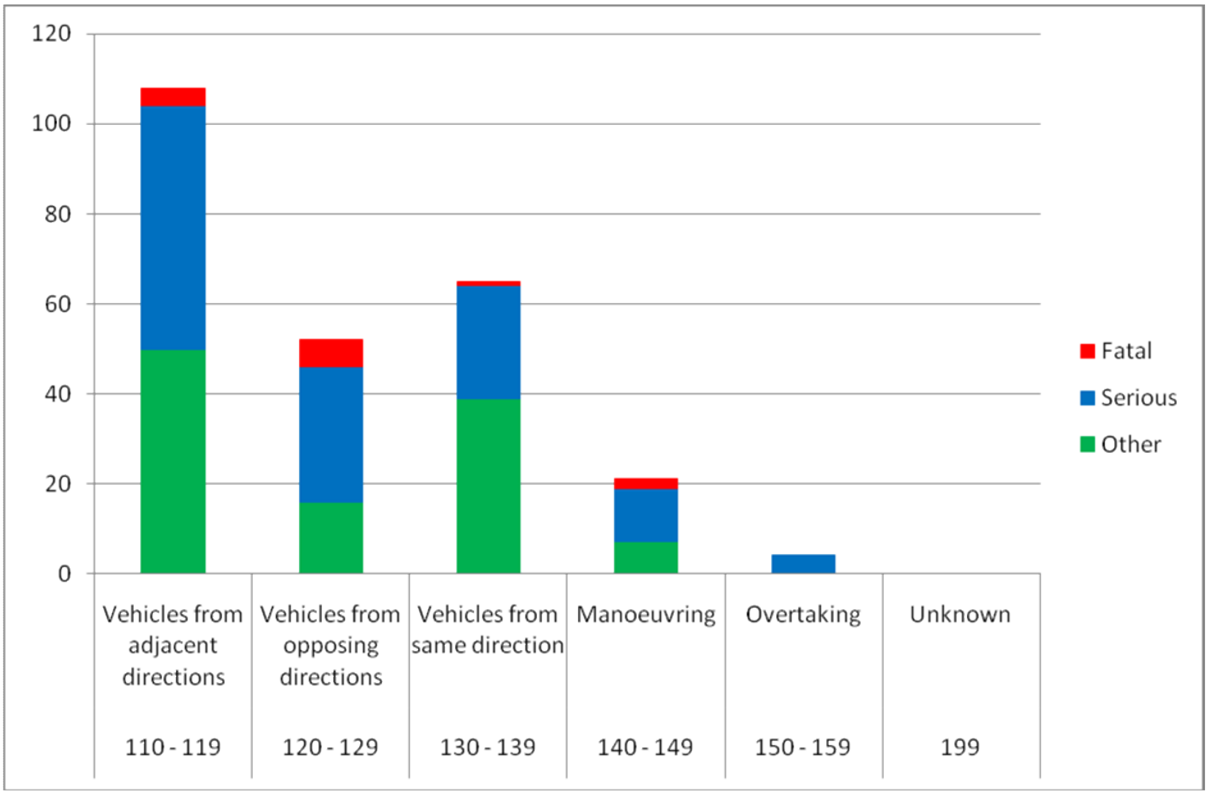


The other injury crashes represent 45% of crashes in this speed zone, with 50% serious injury crashes and 5% involving a fatality. Over 88% of crashes were recorded in metropolitan Melbourne.

Just over half of the crashes in 80km/h speed zones occurred at T-intersections, with 40% occurring at cross intersections. Approximately 35% of crashes occurred in the absence of roundabout or traffic signal control with a further 25% specifically recorded at Give Way sign or Stop sign control. Over 29% occurred at traffic signals with 9% of crashes in 80km/h speed zones occurring at roundabouts.

Figure 25 shows the crash types that occurred in 80km/h speed zones. The data is also presented in Appendix A Table A25.

Figure 25: Crash types present in 80km/h speed zones



The most common types of crashes occurring in this speed zone were Right Through (DCA 121) type crashes representing 20% of crashes in 80km/h speed zones. Right Near (DCA 113) and Cross Traffic (DCA 110) crashes represent a further 29% of crashes together. An additional 8% of crashes were Rear End (DCA 130) crashes and 6% involved vehicles performing U-turns.

Over 64% of crashes were recorded during the day with 23% occurring in dark conditions and the remaining 13% occurring during dusk. Over 89% of crashes occurred in dry conditions with 11% occurring on a wet road surface.

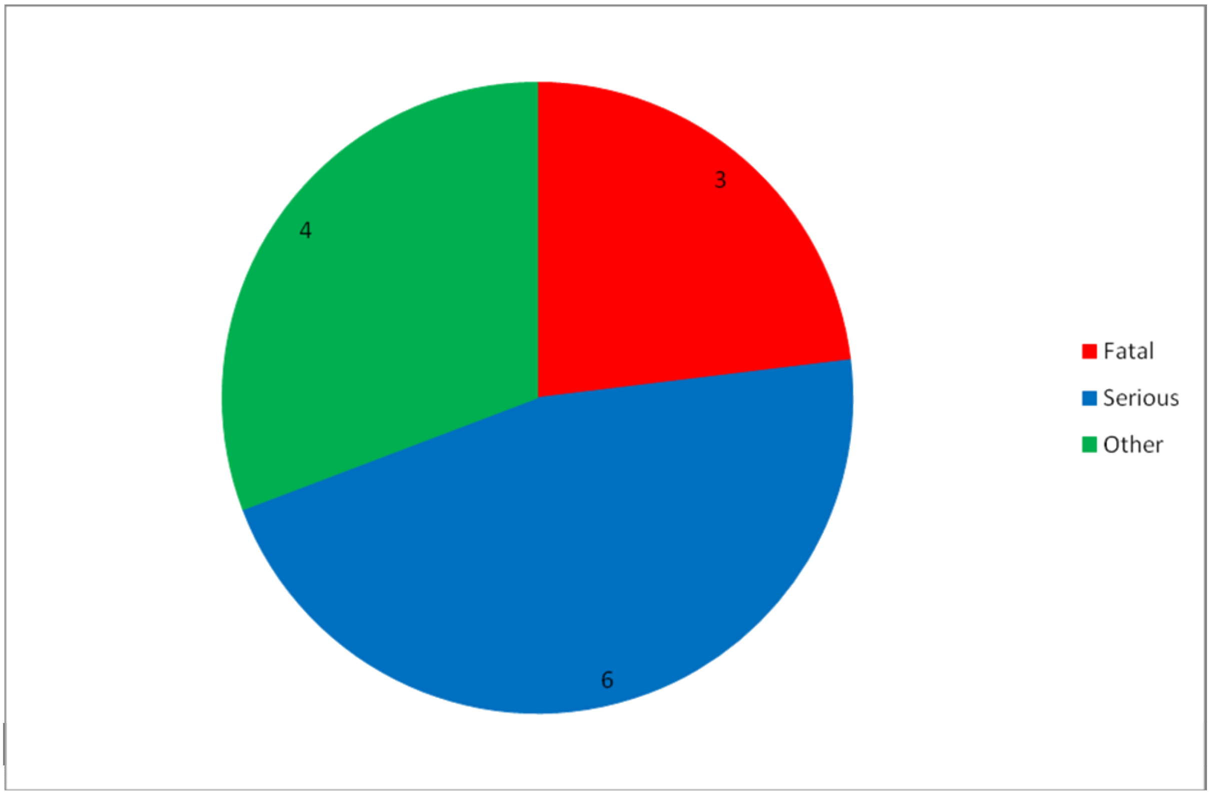
Over 77% of crashes in this speed zone involved driver error as the main factor, including drivers failing to see opposing motorcyclists. Approximately 6% of crashes in this speed zone involved motorcyclists 'lane splitting' or travelling in the kerbside lane adjacent to queued vehicles.

3.8.7 Speed Zone – 90km/h

There have been 13 crashes recorded in 90km/h speed zones involving motorcyclists at intersections. This represents 6% of all motorcycle and motor scooter crashes at intersections which is considerably less than the proportion of crashes occurring in lower speed zones, and the 100km/h speed zone. This is likely to be due to the low prevalence of 90km/h speed zones installed across the road network. With a low number of collisions however, it is difficult to draw robust conclusions about the nature and trend of motorcycle crashes within 90km/h speed zones.

Figure 26 shows the severity of crashes in 90km/h speed zones with the data included in Appendix A Table A26.

Figure 26: Number of crashes by severity in 90km/h speed zones

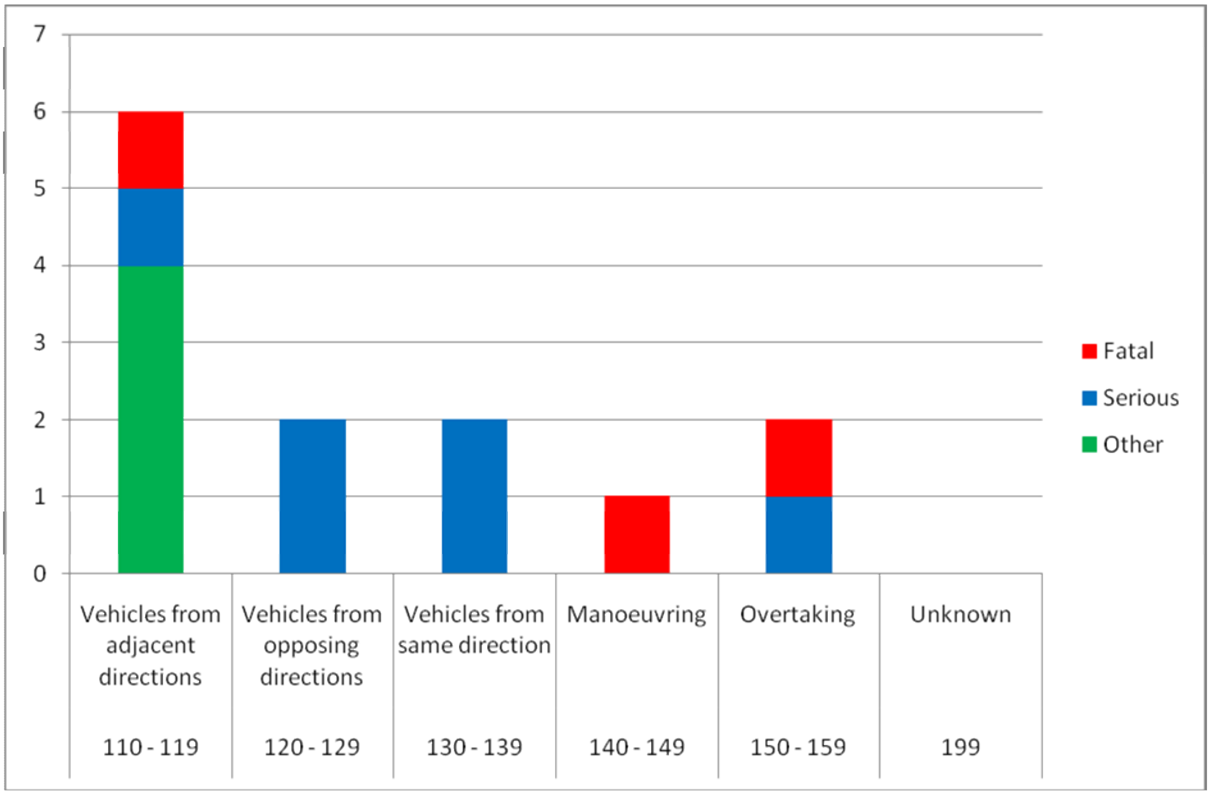


Crashes in this speed zone have generally been at a higher severity with 23% fatal crashes, 46% serious injury crashes and 31% other injury crashes. A greater proportion of crashes occurred in regional Victoria compared to lower speed zones, with 69% of crashes occurring in metropolitan Melbourne.

As per the trend in most other speed zones, over half of the crashes in this speed zone occurred at T-intersections, with 46% occurring at cross intersections. Approximately 69% of crashes occurred in the absence of roundabout or traffic signal control with a further 8% specifically recorded at Give Way sign control. Only 8% have occurred at traffic signals with 15% of crashes in 90km/h speed zones occurring at roundabouts.

Figure 27 shows the crash types that occurred in 90km/h speed zones. The data is also presented in Appendix A Table 27.

Figure 27: Crash types present in 90km/h speed zones



The crash patterns for collisions in this speed zone vary from the crashes at lower speed limits, but it should be noted that there were significantly fewer crashes within 90km/h speed zones than for other speed zones. There is a higher spread of crash patterns, with Lane Change Right (DCA 134) and Pulling Out (DCA 152) crashes together representing 23% of crashes. A further 23% of crashes were Cross Traffic (DCA 110) type crashes with 15% Right Through (DCA 121) and 15% Right Near (DCA 113) type crashes.

In addition, Right Far (DCA 111), Right Rear (DCA 132) and U-turn (DCA 140) crashes each represent 8% of the collisions in this speed zone.

All crashes in this speed zone were recorded in dry conditions with 85% of crashes occurring in daylight.

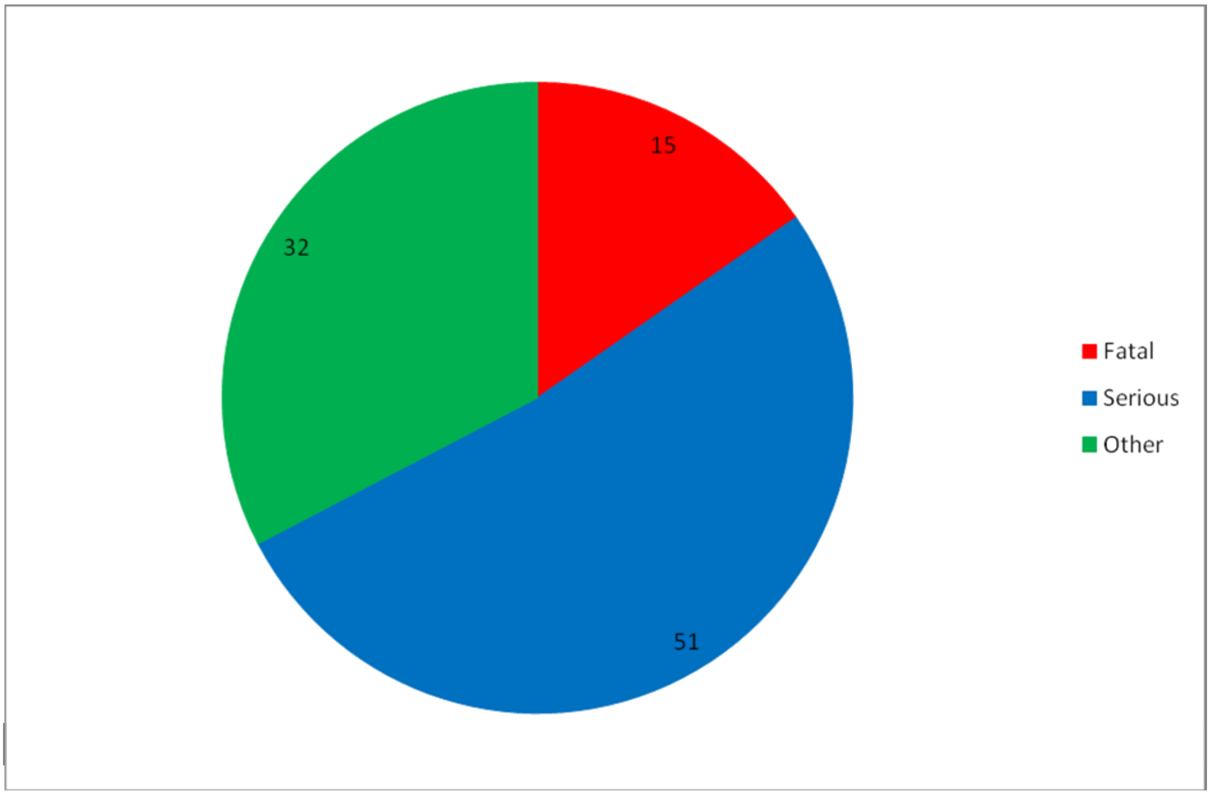
Over 69% of crashes in this speed zone involved driver error as the main factor, including drivers failing to see opposing motorcyclists when turning or changing lanes.

3.8.8 Speed Zone – 100km/h

There have been 98 crashes recorded in 100km/h speed zones involving motorcyclists at intersections.

Figure 28 shows the severity of crashes in 100km/h speed zones with the data included in Appendix A Table A28.

Figure 28: Number of crashes by severity in 100km/h speed zones



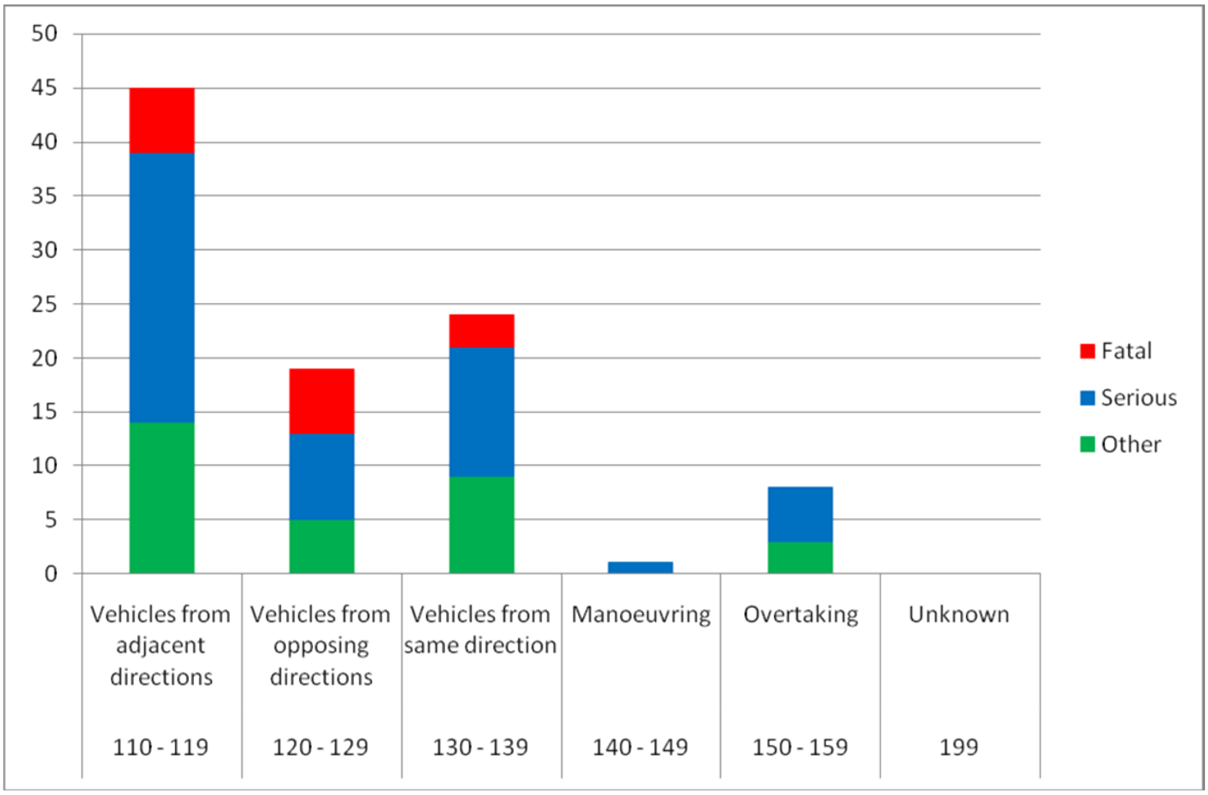
Crashes in this speed zone have generally been at a higher severity with 15% fatal crashes, 52% serious injury crashes and 33% other injury crashes. Over half of the crashes in this speed zone occurred in regional Victoria with only 43% recorded in metropolitan Melbourne.

Almost the same number of crashes in this speed zone have occurred at T-intersections and cross intersections. Contrary to lower speed zones, additional crashes are recorded at Y-intersections (3% of crashes) and multiple / complex intersections (5% of crashes).

Approximately 65% of crashes occurred in the absence of roundabout or traffic signal control with a further 28% specifically recorded at Give Way or Stop sign control. The remaining 7% of crashes in 100km/h speed zones occurred at roundabouts.

Figure 29 shows the crash types that occurred in 100km/h speed zones. The data is also presented in Appendix A Table 29.

Figure 29: Crash types present in 100km/h speed zones



The crash patterns for collisions in this speed zone vary from the crashes at lower speed limits and are similar to the patterns identified for the 90km/h speed zone. There is a higher spread of crash patterns, with Lane Change and Side Swipe (DCA 133 - 137) type crashes representing 12% of collisions, and Pulling Out (DCA 152) crashes representing 8% of crashes.

A further 18% of crashes were Cross Traffic (DCA 110) type crashes with 19% Right Through (DCA 121) and 18% Right Near (DCA 113) type crashes.

In addition, Right Far (DCA 111) and Right Rear (DCA 132) crashes both represent 8% of the collisions in this speed zone.

Ninety-two percent of crashes in this speed zone were recorded in dry conditions with 79% of crashes occurring in daylight.

Over 66% of crashes in this speed zone involved driver error as the main factor, including drivers failing to see motorcyclists. One collision was recorded involving the motorcyclist striking another vehicle and the driver unaware the collision had occurred.

3.8.9 Speed Zone – 110km/h

One collision has been recorded in a 110km/h speed zone involving a motorcyclist turning right into the path of an approaching motorist (Right Far type crash with DCA Code 111). The serious injury collision occurred in dry, daylight conditions on a freeway.

3.9 Intersection Geometry

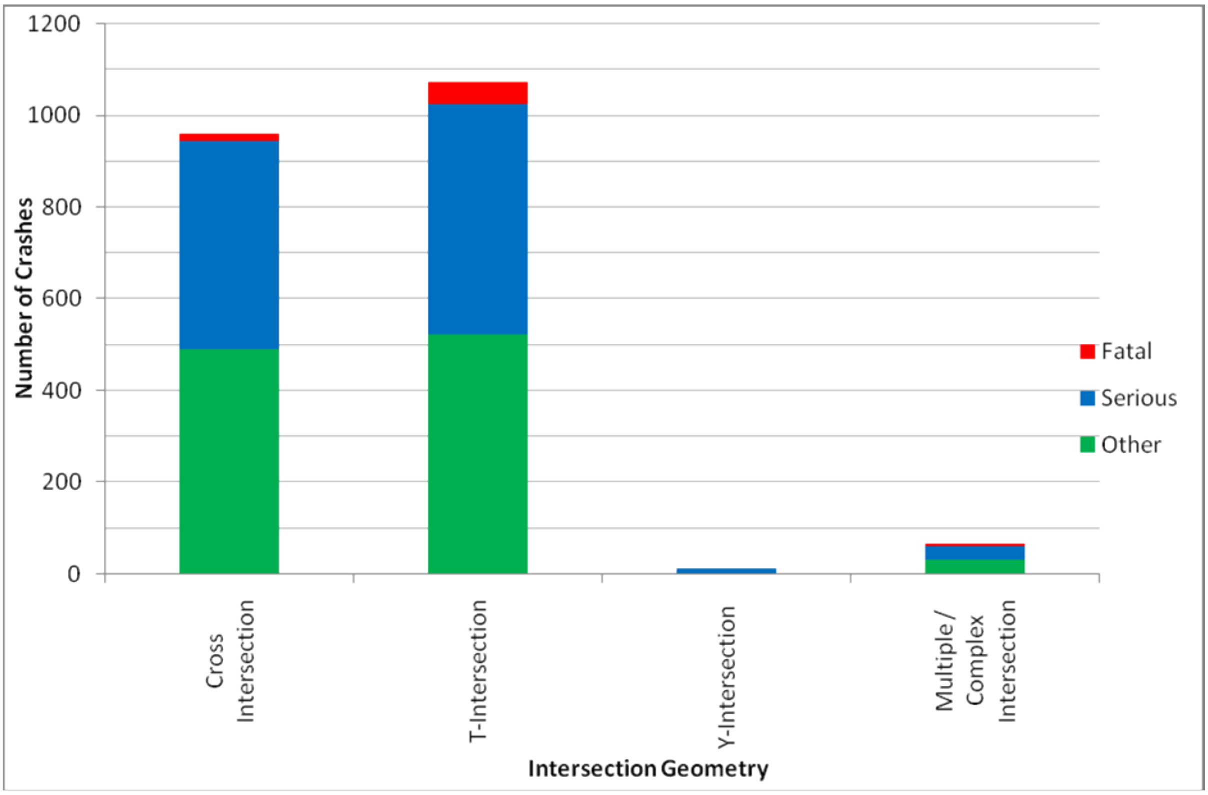
3.9.1 Summary

Four types of intersection geometry are identified in the crash reporting process and provide valuable information on the common intersection design types for motorcycle crashes. The four intersection geometry types analysed are:

- Cross-intersections
- T-intersections
- Y-intersections
- Multiple / complex intersections

Figure 30 shows the number of casualty crashes reported by severity for the four types of intersection geometry (for the five year period). The data for this graph is included in Appendix A Table A30.

Figure 30: Number of casualty crashes by intersection geometry



The data indicates motorcycle crashes at cross-intersections and T-intersections represent more than 96% of the total number of motorcycle crashes at intersections. More than 50% of the crashes have occurred at T-intersections with just over 45% occurring at cross-intersections in the five year period.

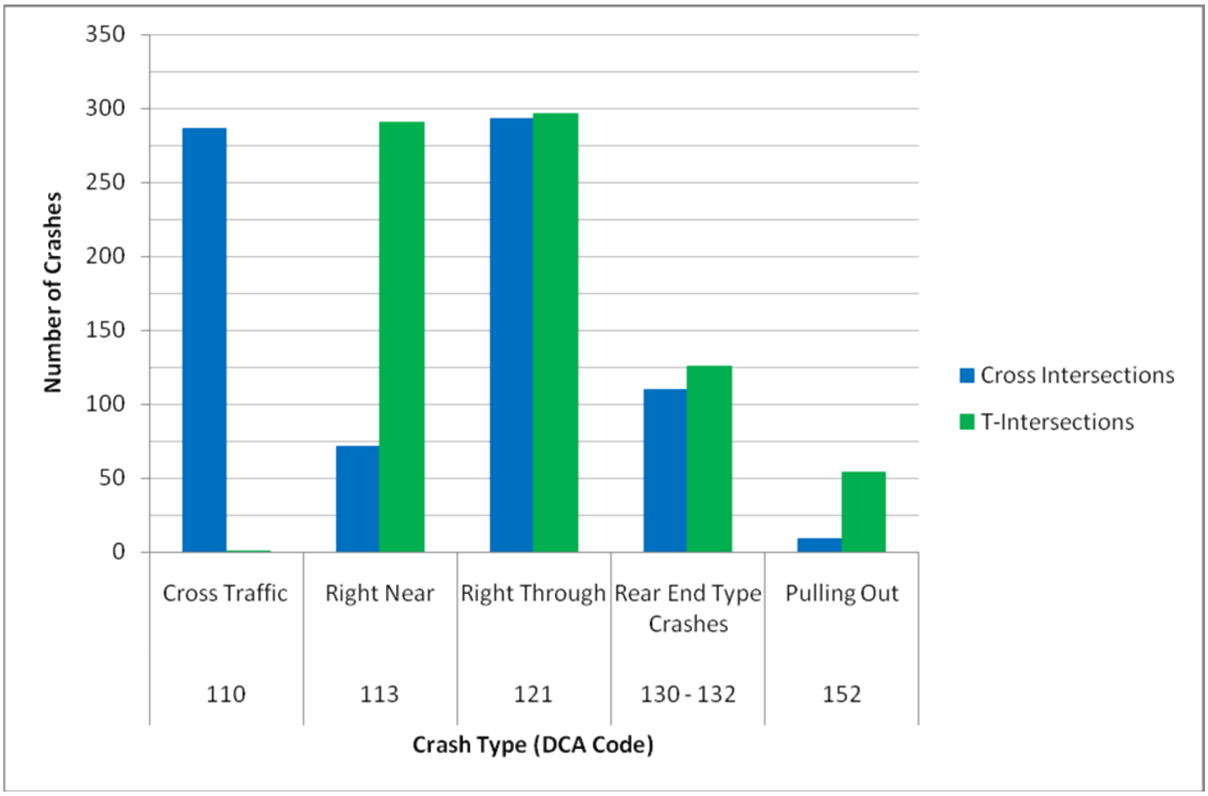
The Y-intersection geometry has been identified in recent years as a high risk type for all road users and a number of road safety projects have addressed this geometry. Realignment of approaches to Y-intersections to create a T-intersection have reduced the number of Y-intersections within the road network. There are relatively few Y-intersections in comparison to the prevalence of cross-intersections and T-intersections in Victoria.

Multiple / complex intersection locations represent sites with multiple roads intersecting at one point and often comprise closely spaced traffic signals that operate as one site. Multiple / complex intersections generally accommodate large traffic volumes in opposing directions.

3.9.2 Cross Intersections and T-Intersections

The characteristics of motorcycle crashes occurring at cross intersections and T-intersections are very similar. Figure 31 shows the crash types which each represent more than 5% of the total intersection crashes for either cross intersections, T-intersections or both. The data is included in Appendix A Table A31.

Figure 31: Number of casualty crashes for common crash types at cross intersections and T-intersections



The data indicates a similar number of Right Through (DCA 121) and Rear End (DCA 130, 131 and 132) type crashes at both cross-intersections and T-intersections.

The data indicates Cross Traffic (DCA 110) type crashes are generally limited to cross intersections as both vehicles are attempting to travel straight through the intersection.

A significant number of Right Near (DCA 113) type crashes occurred at T-intersections, with a greater number of Pulling Out (DCA 152) type crashes also at T-intersections.

The severity of crashes is approximately the same with 47% serious injury crashes at both intersection types, and a further 49% and 51% other injury crashes at T-intersections and cross intersections respectively.

Crashes in dry weather conditions represent 91% of collisions at both intersection types. Crashes occurring in dark conditions represent 20% of crashes at both intersection types, with a further 10% and 12% occurring at dusk at T-intersections and cross intersections respectively.

Driver behaviour is attributed to the collision at 74% and 79% of crashes at T-intersections and cross intersections respectively. The common scenario involved drivers failing to give way to approaching motorcyclists. Some Police reports include descriptions of drivers 'not seeing' the motorcyclist with relatively few estimates of motorcycle speed during the collision.

Approximately 55% of crashes have occurred in 60km/h speed zones for both intersection types with 86% and 80% in metropolitan areas for T-intersections and cross intersections respectively.

The notable difference between the two intersection types is the occurrence of crashes at different intersection control types. Over 40% of cross intersection crashes occurred at signalised intersections with a further 44% at Give Way, Stop sign or 'No Control' sites and 15% at roundabouts. In comparison, 12% of T-intersection crashes occurred at signalised intersections, 86% of crashes occurred at Give Way, Stop sign or 'No Control' sites, and 2% occurred at roundabouts.

While this is a key difference between the two intersection geometry types, it is likely to be more representative of the intersection control types generally installed across the road network rather than an indication of risk to motorcyclists.

3.9.3 Y-Intersections

The crash records indicate 10 motorcycle and motor scooter crashes occurred at intersections during the five year period. The collisions included the following crash types:

- Four crashes involving vehicles from adjacent directions: 1 Cross Traffic (DCA 110) crash, 2 Right Near (DCA 113) crashes and 1 Left Near (DCA 116) crash
- Four crashes involving vehicles from the same direction: 1 Right Rear (DCA 132) crash, 2 Lane Change Left (DCA 135) crashes and 1 Other Same Direction (DCA 139) crash
- One U-turn (DCA 140) crash
- One Miscellaneous (DCA 199) crash

The majority of crashes occurred in metropolitan Melbourne (8 out of the 10 crashes) with 3 crashes occurring in 80km/h speed zones and 3 crashes in 100km/h speed zones. The remaining crashes occurred within speed zones between 50km/h and 70km/h.

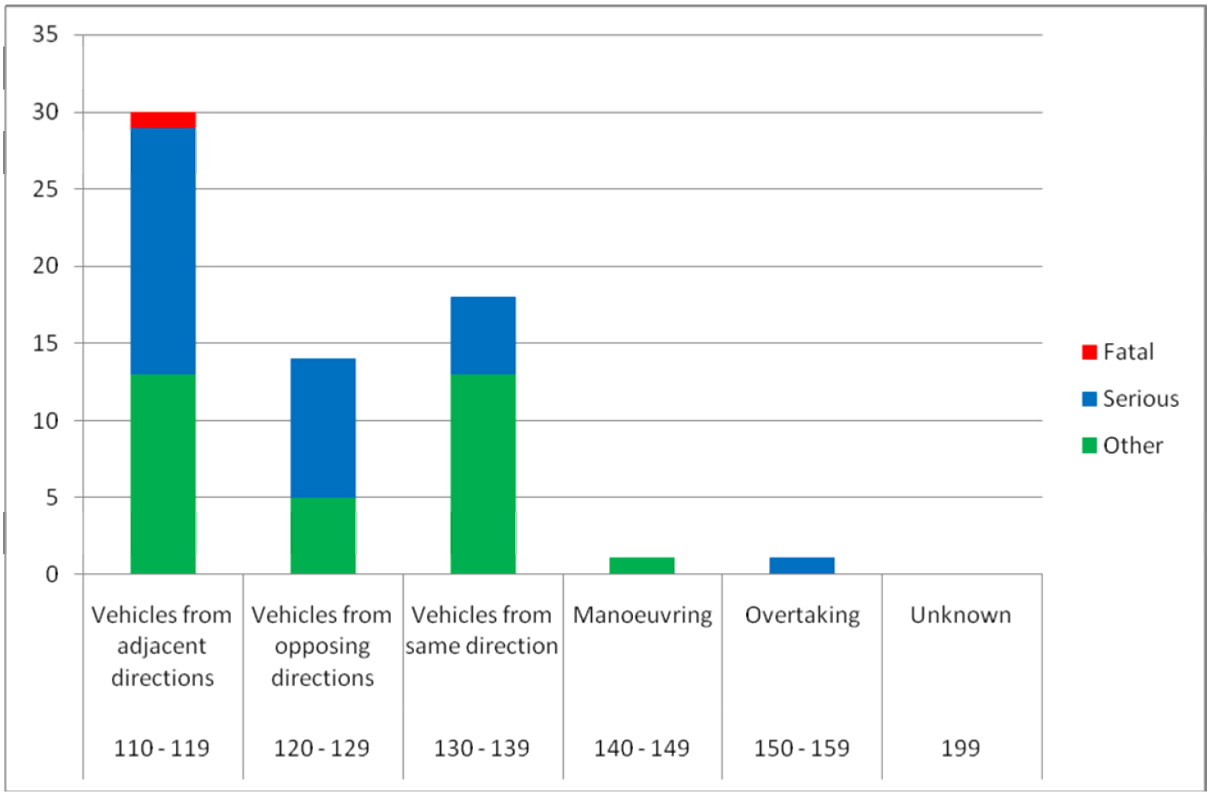
Four of the crashes occurred at dusk and 1 crash occurred in dark conditions, with the remaining 5 crashes occurring during daylight. Nine of the ten crashes occurred in dry conditions with half of the crashes attributed to driver behaviour.

3.9.4 Multiple / Complex Intersections

The analysis indicates 64 motorcycle and motor scooter crashes have occurred at multiple / complex intersections.

Figure 32 shows the types of crashes that have been reported at multiple / complex intersections in the five year period. The data is included in Appendix A Table A32.

Figure 32: Number of crashes for crash types at multiple / complex intersections



The predominant crash types were Cross Traffic (DCA 110) crashes representing 23% of crashes and Right Through (DCA 121) crashes representing 20% of crashes.

Right Far (DCA 111) and Right Near (DCA 113) crashes together represent 19% of crashes at complex intersections, with Left Near (DCA 116) crashes representing a further 5% of crashes.

In addition, lane change and side swipe crashes (DCA 133 – 137) represent 20% of crashes. Rear End (DCA 130 and 131), U-Turn (DCA 140) and Pulling Out (DCA 152) crashes make up the remaining 12% of collisions at complex intersections.

Over 48% of crashes occurred at traffic signals, with roundabouts representing over 20% of crashes and unsignalised sites making up the remaining 32% of crashes.

At the signalised intersections, some of the Police descriptions provided details as to which participant entered the intersection facing a red traffic signal.

At all of the Cross Traffic (DCA 110) crashes with clear Police descriptions (6 of the 15 crashes) the driver of the vehicle entered the intersection facing a red signal lantern.

At all of the Right Through (DCA 121) crashes with clear Police descriptions (3 of the 13 crashes) the motorcyclist was identified as turning right against a red signal lantern.

General analysis of all crashes reported at multiple / complex intersection indicates driver behaviour was attributed to 80% of crashes.

Over 20% of crashes occurred in dark conditions, with over 10% at dusk. Over 93% occurred in dry conditions with over 6% with a wet road surface.

Over 85% of the multiple / complex intersections were within metropolitan Melbourne which is likely to be due to the number of complex intersections in the metropolitan area. As per the general trend of crashes, over 60% occurred in a 60km/h speed zone.

3.10 Intersection Control

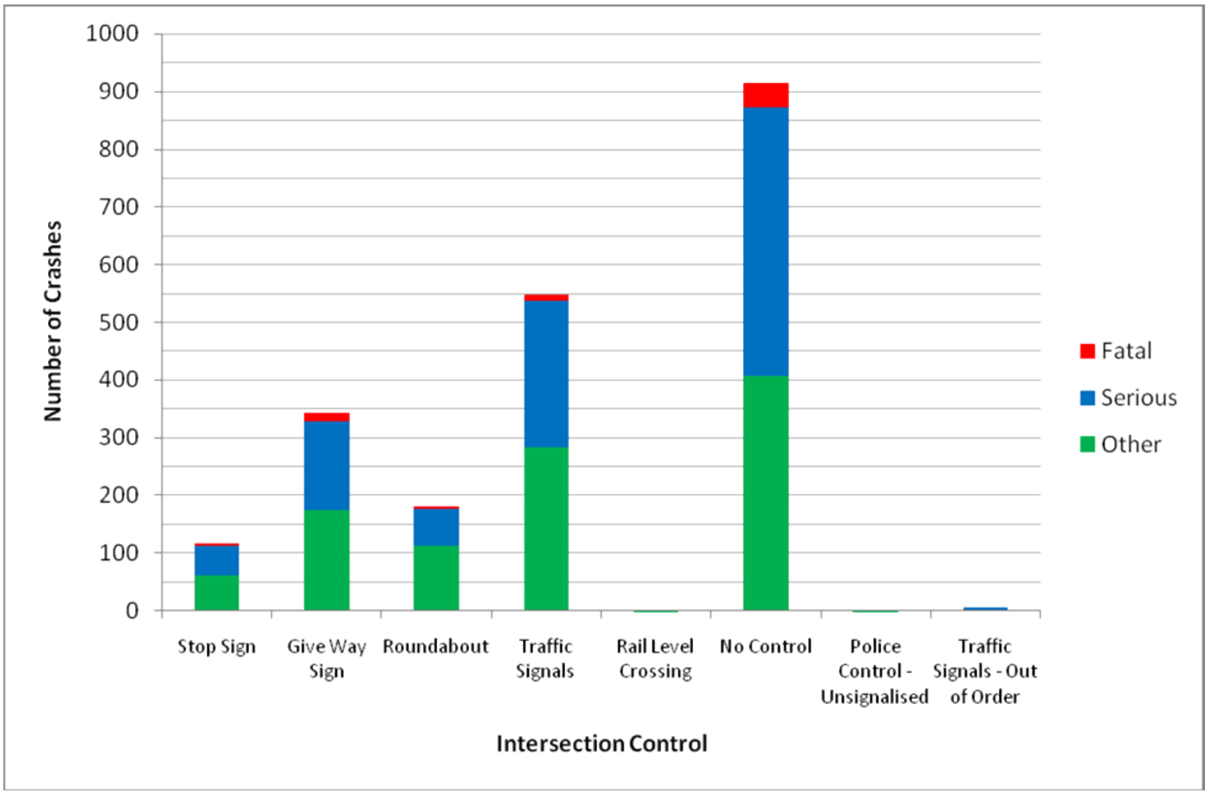
3.10.1 Summary

The type of intersection control has been analysed for the motorcycle and motor scooter crashes. The following types of intersection control have been identified for further analysis:

- Traffic signals
- Traffic signals – out of order – which comprises sites with flashing amber lights or blank displays
- Roundabout
- No control – which primarily comprises crashes occurring on a priority road involving vehicles turning left or right, which are not controlled by traffic signals. This label also includes Stop sign and Give Way sign controlled intersections in some instances where Police have reported No Control rather than Stop or Give Way sign control.
- Give Way sign
- Stop sign
- Police control at unsignalised intersections – which comprises Police-directed detours
- Rail Level Crossing (identified as Bells and Flashing Lights in RCIS Data)

Figure 33 shows the number of casualty crashes reported by severity for each intersection control type over the five year period. The data for this graph is included in Appendix A Table A33.

Figure 33: Number of casualty crashes by intersection control



The data indicates 26% of motorcycle intersection crashes occurred at signalised intersections and 9% occurred at roundabouts. Over 16% occurred at Give Way sign controlled intersections and 6% were recorded at Stop Sign controlled intersections.

Intersections with 'No Control' represent over 43% of motorcycle crashes which predominantly comprises uncontrolled movements left or right from the priority road into adjacent Give Way or Stop Sign controlled roads.

A further 0.5% of motorcycle crashes occurred at level crossings (1 crash), intersections controlled by Police (2 crashes) and signalised intersections while the signals were out of order (5 crashes).

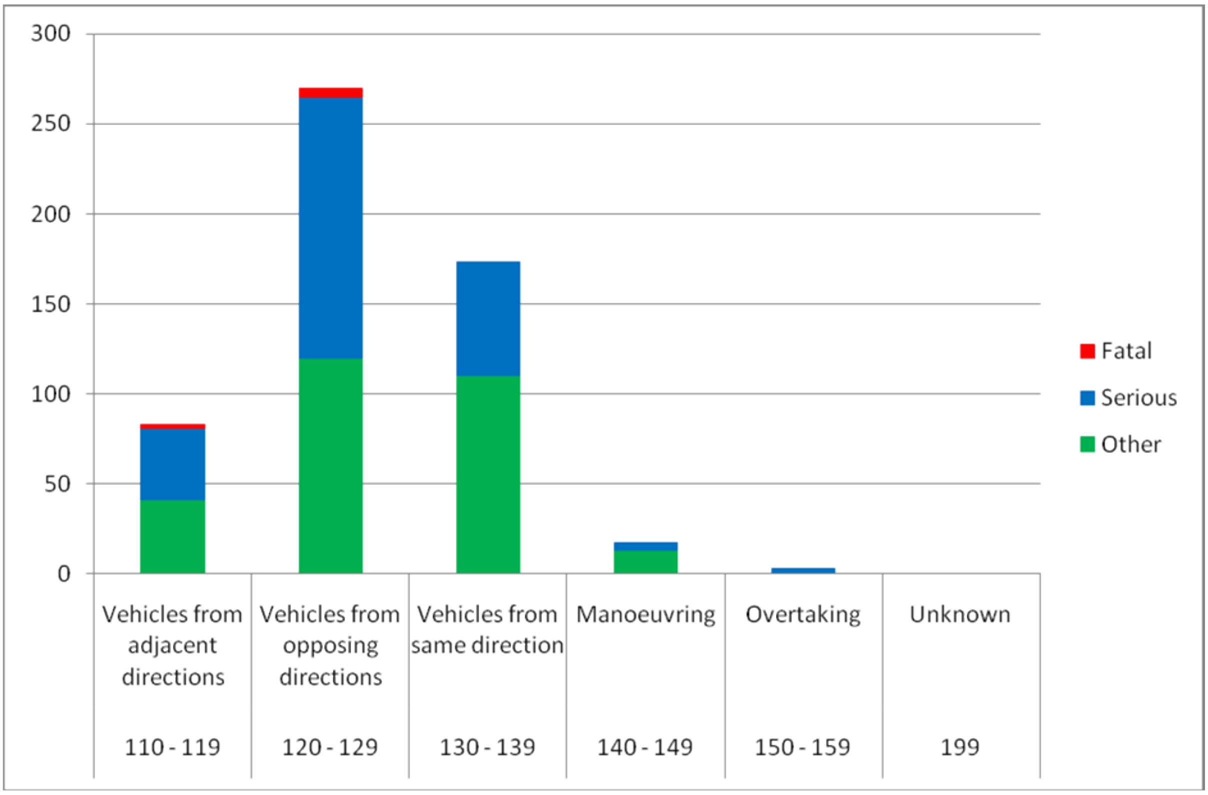
The key factors and common crash scenarios for the main types of intersection control are discussed in the following sections.

3.10.2 Traffic Signals

There were 546 motorcycle and motor scooter crashes recorded at signalised intersections over the five year period.

The range of crash types are shown in Figure 34 with the source data included in Appendix A Table A34.

Figure 34: Traffic Signals - Number of casualty crashes by DCA crash group



A range of crashes were reported with nearly half of the crashes (48%) being Right Through (DCA 121) crashes and nearly one third of crashes (32%) involved vehicles approaching from the same direction (DCA 130 – 139).

Fifteen percent of crashes involved vehicles from adjacent directions including Cross Traffic (DCA 110), Right Far (DCA 111), Right Near (DCA 113), Two Right Turning (DCA 114) and Left Near (DCA 116). These crashes are generally not expected at signalised intersections and involve one or more participants entering the intersection facing a red signal lantern.

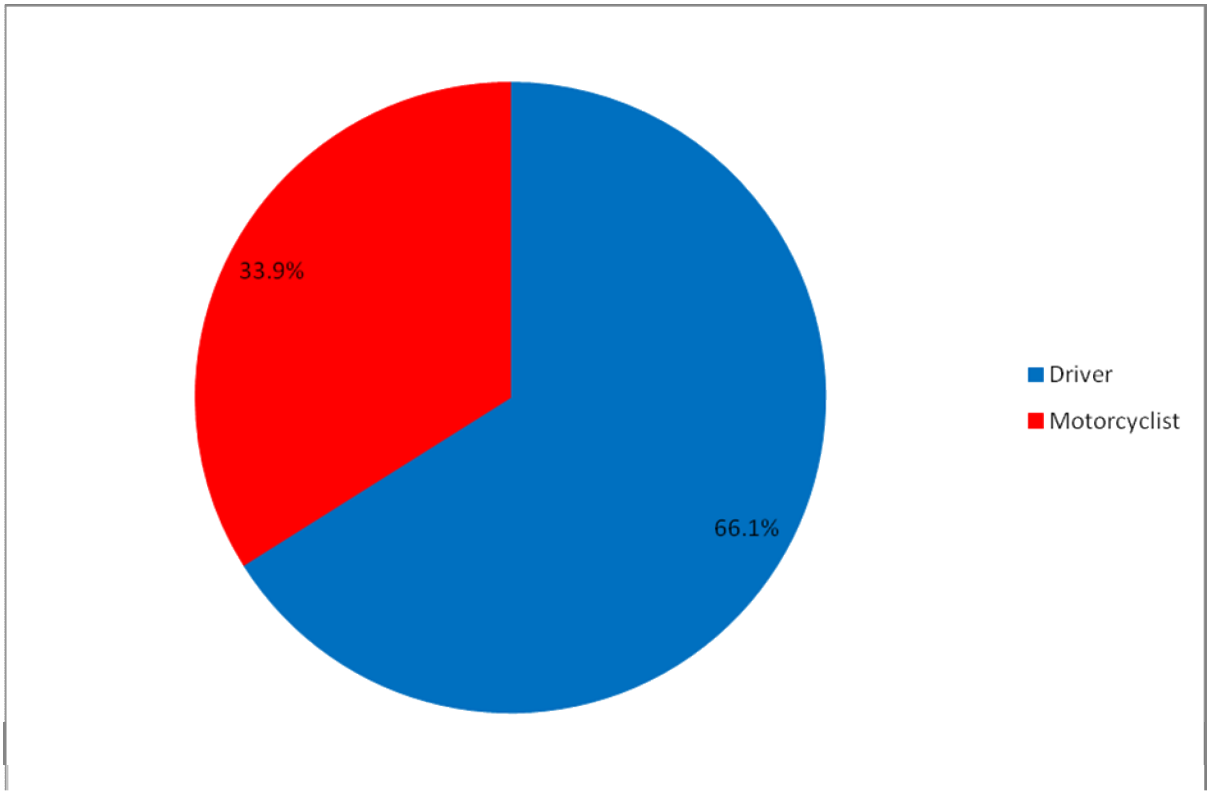
The remaining crashes comprised U-Turn (DCA 140), Emerging From Driveway / Laneway (DCA 147), Emerging From Footway (DCA 148), Other Manoeuvring (DCA 149) and Pulling Out (DCA 152) crashes. These crashes together represent 4% of the motorcycle crashes recorded at signalised intersections.

3.10.2.1 Cross Traffic (and Similar) Crashes

Crashes involving vehicles from adjacent directions generally involve one or more participants entering the intersection against a red signal display. Of the 83 crashes reported within this crash group, 56 of the Police descriptions identified which vehicle 'ran a red light'.

Figure 35 shows the proportion of crashes involving drivers and motorcyclists entering the intersection facing a red signal display, with the data also included in Appendix A Table A35.

Figure 35: Cross Traffic (DCA Code 110) crashes at signalised intersections – participant entering the intersection facing a red signal display



A general assessment of behaviour affecting the crash revealed that driver error accounted for 58% of crashes, whilst motorcyclist error accounted for 30%, with a further 12% of crashes undetermined. Two thirds of the cross traffic crashes at traffic signals (66%) involved drivers entering the intersection against a red signal, and one third of crashes (34%) involved the motorcyclist entering the intersection illegally.

Some crash reports included a description of the motorcyclist attempting to stop and sliding or skidding into the intersection facing a red signal lantern and striking an opposing vehicle.

Nearly 90% of crashes occurred in dry conditions with 10% occurring with a wet road surface.

A third of the cross traffic (and similar) crashes occurred in dusk or dark conditions and all crashes in this group occurred while traffic signals were operating correctly. Further analysis indicates 83% of the crashes at dusk involved one of the participants travelling west. This indicates the driver or the motorcyclist were facing the setting sun which may have affected the visibility of the signals and the surrounding vehicles.

In half of the cases at dusk with one participant driving west, the motorcyclist was riding west and the other 50% involved the driver of the other vehicle facing west. Limited data from the Police reports indicates 75% of the confirmed incidents with a vehicle driver entering the intersection facing a red signal at dusk involved the driver facing west, and similarly, 67% of the confirmed incidents of a motorcyclist entering the intersection facing a red display at dusk involved the motorcyclist riding west.

The crashes in this crash group occurred most often at signals installed at cross intersections (59%) with further crashes recorded at T-intersections (28%) and the remaining 13% at multiple / complex signalised intersections.

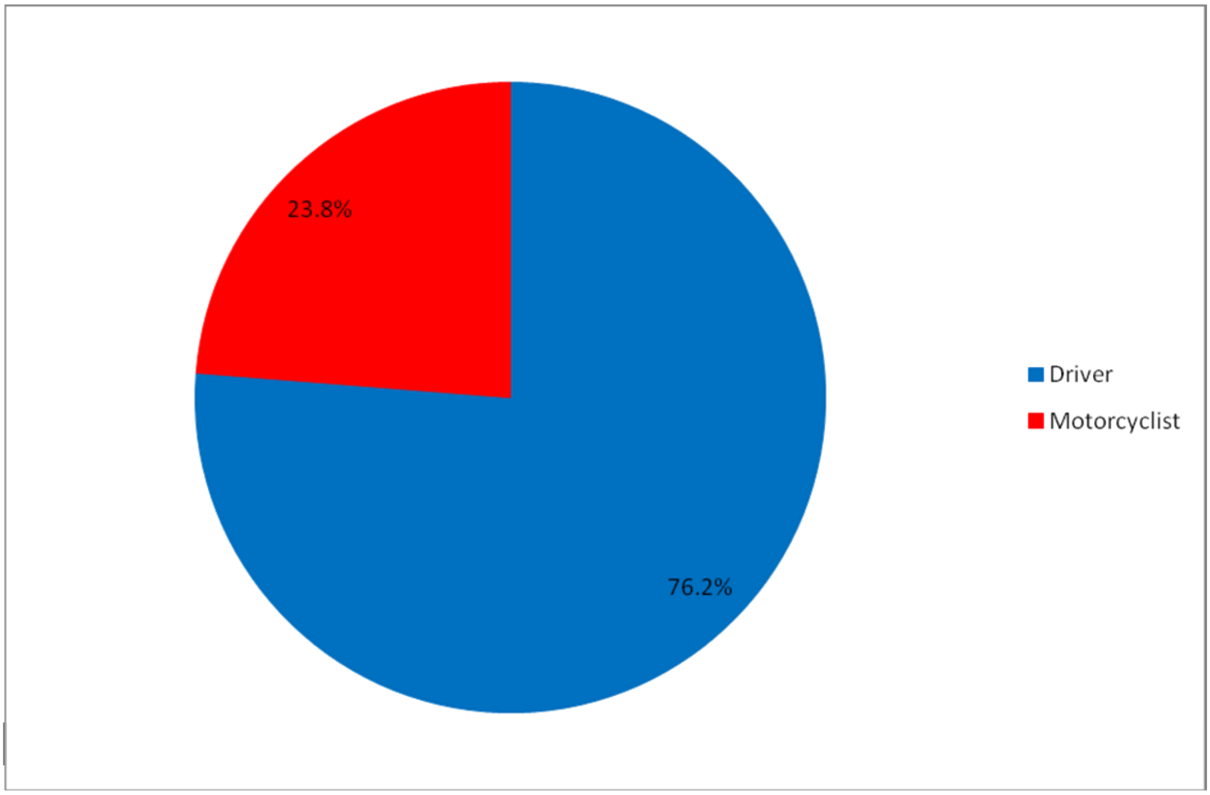
All of these crashes occurred in speed zones between 50km/h and 80km/h, with over half of the crashes (54%) occurring in 60km/h speed zones.

3.10.2.2 Right Through Crashes

Right Through crashes represented 48% of crashes at signalised intersections with 261 crashes reported during the five year period.

Figure 36 shows the proportion of crashes involving the motorcyclist turning right compared with the crashes involving the driver turning right and the data is also shown in Appendix A Table A36.

Figure 36: Right Through (DCA Code 121) crashes at signalised intersections – participant turning right during the crash



Analysis of the data indicates the driver of the vehicle was turning right (and the motorcyclist traveling straight) during 76% of Right Through crashes. The analysis did not specifically address whether the right turns were fully controlled or filtered turns with only 6 Police reports confirming right turn movements filtered across the intersection.

The Police descriptions indicate an equal number of crashes reported for motorcyclists and drivers entering the intersection facing a red signal lantern. The Police reports confirm 13 crashes (5% of the total crashes) involved motorcyclists facing a red signal display, and the same number of crashes involved the driver of the vehicle entered the intersection facing a red signal display.

The Police reports indicate at least 4% of crashes involved both the motorcyclist and driver entered the intersection at the end of a phase while the signal displays to both approaches were amber.

Motorcyclists were identified to be lane splitting in 2% of the crashes, and similarly, travelling in the kerbside lane adjacent to queued vehicles in a further 2% of the crashes.

Over 90% of crashes occurred in dry conditions with 8% occurring with a wet road surface and a further 2% unknown.

Over a third of the Right Through crashes occurred in dusk or dark conditions (39%) and all crashes in this group occurred while traffic signals were operating correctly. Further analysis indicates 60% of the crashes at dusk involved one of the participants travelling west. This indicates the driver or the motorcyclist were facing the setting sun which may have affected the visibility of the signals and the surrounding vehicles.

In 55% of the cases at dusk with one participant driving west, the motorcyclist was riding west and the other 45% involved the driver of the other vehicle facing west. Limited data from the Police reports indicates 67% of the confirmed incidents of a motorcyclist entering the intersection facing a red display at dusk involved the motorcyclist riding west, facing the setting sun.

The crashes in this crash group occurred most often at signals installed at cross intersections (77%) with further crashes recorded at T-intersections (19%) and the remaining 4% at multiple / complex signalised intersections.

All crashes occurred in speed zones between 40km/h and 80km/h, with two-thirds of the crashes (67%) occurring in 60km/h speed zones.

3.10.2.3 Rear End Crashes

Rear End, Left Rear and Right Rear crashes represented 16% of crashes at signalised intersections with 86 collisions reported during the five year period.

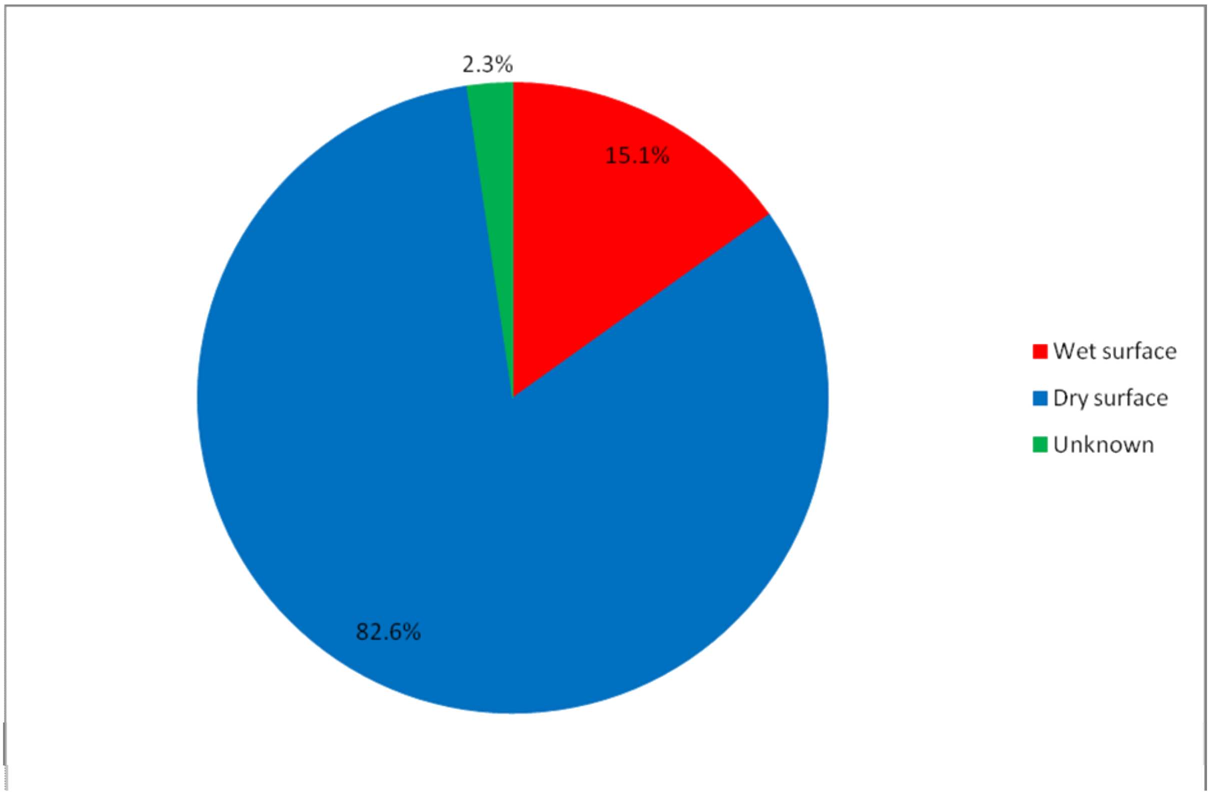
The severity of these crashes was generally lower than the overall motorcycle intersection crashes and comprised 63% other injury crashes, 37% serious injury crashes and no fatalities. The Police reports confirmed at least 18% of crashes involved motorcyclists being stationary at the intersection when the collision occurred.

Three rear end crashes were reported to occur when vehicles or motorcyclists stopped at the intersection to allow an opposing emergency vehicle to travel through the intersection. This represents 4% of this group of crashes.

A general assessment of the crashes attributes driver behaviour to 54% of the crashes, and motorcyclist behaviour to 46% of rear end crashes.

Figure 37 shows the proportion of rear end type crashes that occurred during wet weather compared to dry road conditions. The data is also shown in Appendix A Table A37.

Figure 37: Road surface conditions at the time of the rear end type
(DCA Codes 130, 131 and 132) crashes at signalised intersections



Over 15% of rear end type crashes occurred in wet conditions which is a greater proportion than recorded at other prevalent crash types at signalised intersections. Over 82% of crashes occurred in dry conditions with a further 2% unknown.

Under a third of the rear end type crashes occurred in dusk or dark conditions (29%) and all crashes in this group occurred while traffic signals were operating correctly. Two crashes (2% of rear end type crashes) involved a westbound vehicle and westbound motorcyclist colliding at dusk.

The crashes in this crash group occurred most often at signals installed at cross intersections (70%) with further crashes recorded at T-intersections (27%) and the remaining 4% at multiple / complex signalised intersections.

All crashes occurred in speed zones between 40km/h and 90km/h, with over a half of the crashes (54%) occurring in 60km/h speed zones. Crashes in 70km/h speed zones represented 19% of rear end type crashes, and 80km/h speed zones represent a further 17% of this group of crashes.

3.10.2.4 Side Swipe and Lane Change Crashes

Side swipe and lane change type crashes represent 15% of crashes involving motorcyclists at signalised intersections. Nine of these crashes (10% of the side swipe and lane change type crashes) involved hook turn manoeuvres which are considered in a separate section of this report.

Of the remaining crashes, 43% involved one of the participants changing lanes at the intersection. Over 90% of these lane changes involved the driver changing lanes and striking the motorcyclist.

Approximately 10% of this group of crashes occurred with participants changing lanes to overtake a vehicle propped to turn at the intersection. Three quarters of crashes involving this scenario involved a motorcyclist changing lanes to overtake a vehicle propped to turn at the intersection, and consequently striking a vehicle in an adjacent traffic lane.

Over 10% of crashes within this group involved both participants attempting to turn at the intersection and the vehicle and motorcyclist colliding during the turn.

In addition, 20% of crashes within this group involved the driver of a vehicle striking a motorcyclist while turning. This was generally due to vehicles turning from a far traffic lane (e.g. attempting to turn right from the left lane), or turning across an outer separator (e.g. attempting to turn left from the centre carriageway rather than from the service road).

Similarly with the rear end type crashes, the severity of the lane change and side swipe crashes was generally lower than the average motorcycle intersection crashes and involved 61% other injury crashes, 39% serious injury crashes and no fatalities.

A general assessment of the crashes attributed driver behaviour to 80% of the crashes, and motorcyclist behaviour to 17% of lane change and side swipe type crashes. Over 90% of crashes occurred in dry conditions with 5% occurring on a wet road surface.

Over a quarter of lane change and side swipe type crashes occurred in dark conditions and a further 8% occurred at dusk. The remaining 67% of crashes occurred during daylight hours. All crashes in this group occurred while traffic signals were operating correctly.

The crashes in this crash group occurred most often at signals installed at cross intersections (69%) with further crashes recorded at T-intersections (25%) and the remaining 5% at multiple / complex signalised intersections.

All crashes occurred in speed zones between 40km/h and 80km/h, with over a half of the crashes (59%) occurring in 60km/h speed zones. Crashes in 50km/h and 70km/h speed zones both represented 15% of side swipe and lane change type crashes, and 80km/h speed zones represent a further 11% of this group of crashes.

3.10.2.5 Hook Turns

Hook turn manoeuvres were involved in 3% of all crashes involving motorcycles at signalised intersections.

Analysis indicates 65% of hook turn crashes involved the driver of a vehicle attempting to complete the hook turn and a further 12% of descriptions were unclear as to which participant was attempting a hook turn.

Over 90% of crashes with drivers completing hook turns involved driver error in this process. The Police reports confirmed the common mistake of drivers turning right from the propped position prior to the applicable green signal lantern display, and in some instances, prior to the signals in the initial direction of travel turning red.

3.10.2.6 Additional Factors at Signalised Intersections

The Police reports confirmed 2% of crashes at signalised intersections occurred while the signal displays were amber at which time Right Through type crashes and Rear End crashes occurred.

The Police reports confirmed motorcyclists lane splitting through queued vehicles during 1% of crashes occurring at signalised intersections. A further 1% involved motorcyclists travelling in the kerbside lane adjacent to a traffic lane of queued vehicles. All of these incidents involved vehicles turning right across the queue of vehicles and striking the motorcyclist.

The Police reports confirmed 2% of crashes at signalised intersections occurred when motorcyclists or vehicles entered the intersection facing a green signal while vehicles or motorcyclists from the previous phase were yet to clear the intersection. This included vehicles (and one motorcyclist) turning right at the end of a phase, in addition to vehicles queuing through the intersection and blocking traffic lanes.

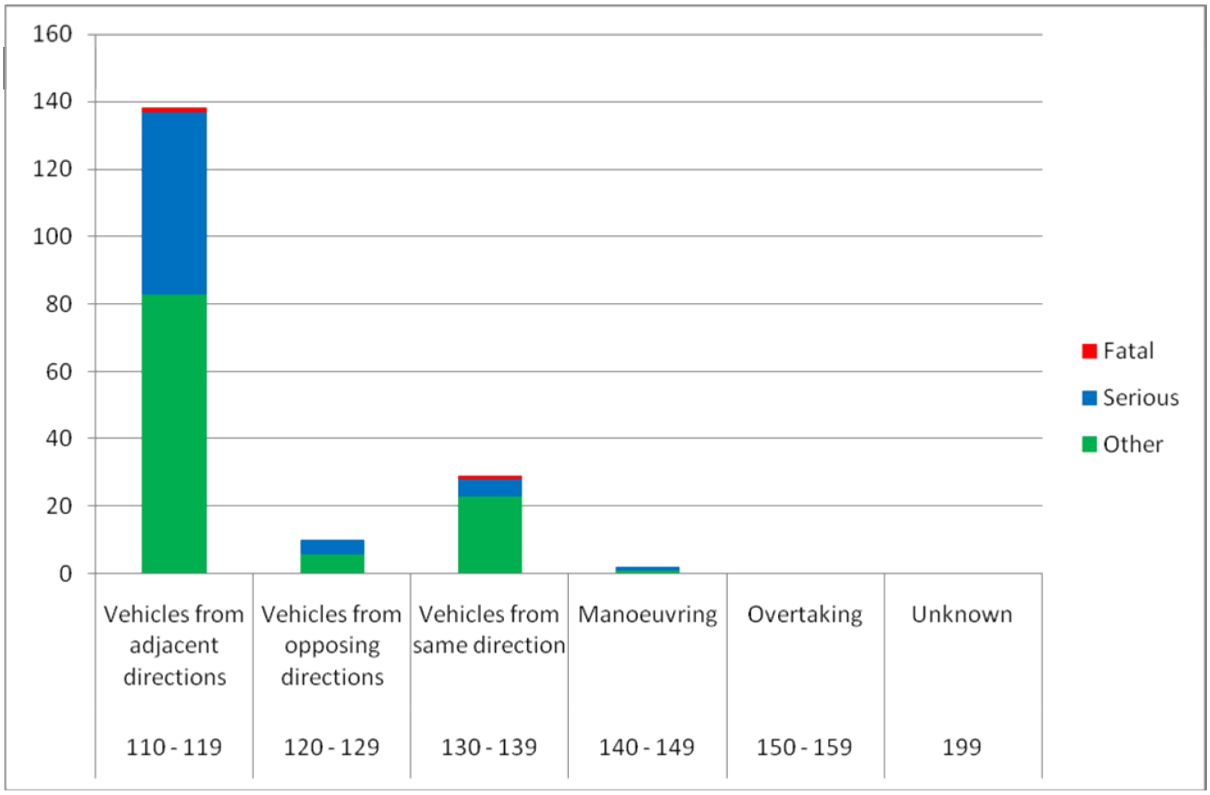
The analysis indicates 3% of collisions involved motorcyclists or vehicles turning illegally with 1% of crashes involving a driver turning right against a right turn ban, and 1% of crashes involving a driver turning left from the right lane, or from the centre carriageway across a service road.

3.10.3 Roundabouts

Collisions at roundabouts represented 9% of all motorcycle intersection crashes with 179 crashes reported during the five year period. These crashes comprised 63% other injury crashes, 36% serious injury crashes and 1% resulted in fatalities.

The range of crash types are shown in Figure 38 with the source data included in Appendix A Table A38.

Figure 38: Number of casualty crashes by DCA crash group at roundabouts



The most common type of crashes reported at roundabouts involved a vehicle and motorcycle approaching from adjacent directions which represented 77% of crashes at roundabouts. A further 16% of crashes involved a vehicle and motorcyclist travelling in the same direction and 6% involved vehicles from opposing directions.

It is noted that the road alignment on the approach to the roundabout influences the speed of vehicles (and motorcyclists) approaching the roundabout. A clear deflection in the lane alignment will often reduce the speed of vehicles approaching the intersection. Motorcyclists may navigate these deflections at a higher speed than vehicles by utilising the full lane width on the approach to the roundabout.

In accordance with the Road Rules, priority at the intersection is given to the vehicle first to enter the roundabout which will often be on the right hand side of a driver (or motorcyclist) approaching the intersection.

3.10.3.1 Cross Traffic Type Crashes

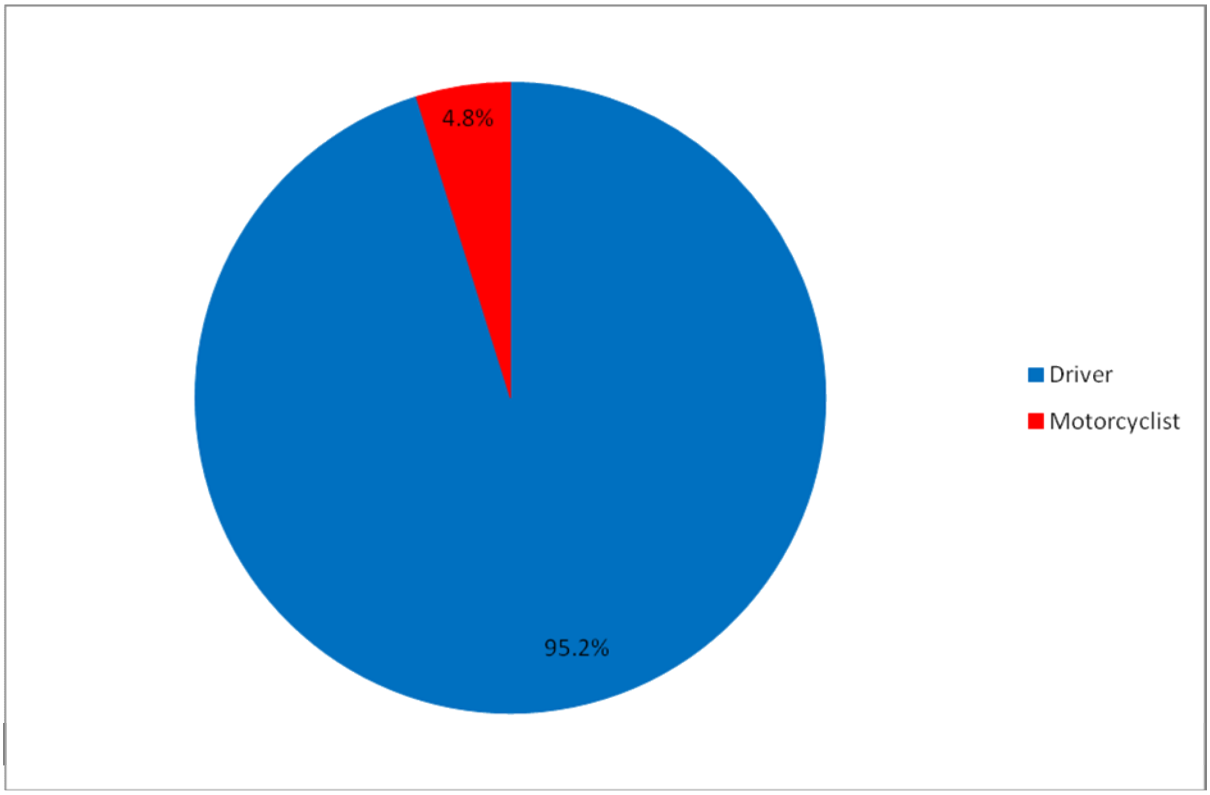
The cross traffic type crashes represented 77% of all motorcycle crashes occurring at roundabouts in the five year period.

The predominant crash types involved vehicles approaching the roundabout and failing to give way to a motorcyclist already within the roundabout; and vehicles colliding with motorcyclists entering the roundabout on the right hand side of the driver.

The Police reports and crash descriptions did not consistently provide a level of detail suitable to clearly distinguish between the number of crashes involving motorcyclists already within the roundabout compared with the number of crashes involving motorcyclists approaching the roundabout.

Figure 39 shows the proportion of crashes involving a driver failing to give way to a motorcyclist and conversely, motorcyclists failing to give way to other vehicles. The data for this graph is also shown in Appendix A Table A39.

Figure 39: Proportion of cross traffic type crashes at roundabouts involving each participant failing to give way



The Police reports of these collisions did not provide a fine level of detail for the specific reasons for the collisions. The descriptions did not clarify whether drivers did not identify motorcyclists, did not accurately assess the speed of the motorcyclist, or whether the motorcyclist was travelling at excessive speed on the approach to or within the roundabout.

The Police reports for only two collisions (1% of all motorcycle crashes at roundabouts) included allegations of motorcyclists approaching the roundabout at high speed. Similarly, there were few descriptions of motorcyclist behaviour, or indication that the vehicle had entered the intersection prior to the motorcyclist entering the roundabout on the right hand side of the vehicle.

Newer cars tend to have wider frames adjacent to the windscreen compared with older cars and the frames can hide motorcyclists and cyclists. The width of the frames may have contributed to drivers not identifying the approaching motorcyclist in some of the crashes.

A further 5% of crashes involved motorcyclists failing to give way to vehicles within the roundabout. One collision included the presence of 'sun glare' restricting the motorcyclist's ability to identify approaching vehicles.

The crashes generally occurred at cross intersections (83%) with 10% occurring at a roundabout configured at a T-intersection and the remaining 7% occurring at multiple / complex intersections.

The collisions generally occurred in dry conditions with 8% recorded a wet road surface.

While the majority of crashes occurred during the day, 14% occurred at dusk and 13% occurred in dark conditions. The absence of adequate lighting may have contributed to these crashes with the additional difficulty of drivers recognising one headlight as a motorcyclist rather than two headlights which are present on vehicles.

Half of the collisions occurred in 60km/h speed zones with over 20% in 50km/h speed zones, and a further 20% in 70km/h and 80km/h speed zones combined.

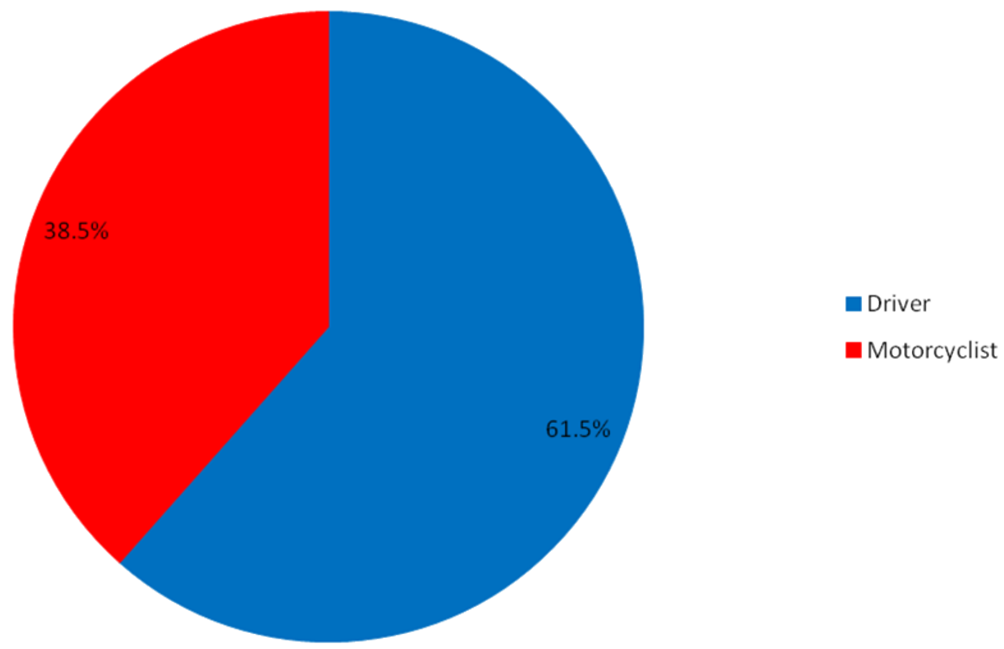
The severity of the cross traffic type crashes at roundabouts was generally lower than the average motorcycle and motor scooter crashes at all intersection control types. The cross traffic type crashes at roundabouts resulted in 60% other injury crashes, 39% serious injury crashes and 1% resulted in fatalities.

3.10.3.2 Collisions on Approach to the Roundabout

Crashes occurring on the approaches to roundabouts represented 7% of all collisions at roundabouts in the five year period.

Figure 40 shows the proportion of crashes involving a driver failing to stop (labelled 'Driver') and a motorcyclist failing to stop before striking a vehicle (labelled 'Motorcyclist'). This data is included in Appendix A Table A40.

Figure 40: Proportion of crashes involving each participant failing to stop during crashes on the approaches to roundabouts



A general assessment of these type of crashes indicated drivers struck the rear of motorcyclists in 62% of these crashes, and motorcyclists struck the rear of vehicles in the remaining 39% of collisions.

Almost a third (31%) of these crashes occurred in dark conditions and a further 8% at dusk. Crashes in daylight represented only 62% of collisions on the approach to a roundabout.

The weather conditions were generally dry (85%) with 8% of crashes occurring on a wet road surface and a further 8% occurring in unknown conditions.

The majority of crashes (77%) occurred in a 60km/h speed zone with 15% in an 80km/h speed zone and the remaining 8% in a 50km/h speed zone.

The severity of these crashes was low with 85% other injury crashes and 15% serious injury crashes.

The crashes in this group occurred most often at roundabouts at cross intersections (77%) with further crashes recorded at T-intersections (15%) and the remaining 8% at multiple / complex roundabout intersections.

The Police reports for these type of crashes did not provide clear indications of factors relating to the cause of the crashes.

3.10.3.3 Collisions Within Multi-Lane Roundabouts

Crashes occurring within multi-lane roundabouts represented 9% of all motorcycle crashes at roundabouts (16 crashes out of the 177 collisions at roundabouts).

The factors contributing to these crashes included drivers changing lanes within the roundabout (25% of crashes) and drivers attempting to turn right from the left lane (29% of crashes). A further 13% of crashes involved both the motorcyclist and vehicle attempting to turn in the same direction and colliding during the turn.

Motorcyclists were identified to be changing lanes within the roundabout at 6% of crashes, and attempting to overtake a vehicle within the roundabout at a further 6% of crashes.

The crashes generally occurred in dry conditions (94% of crashes) during daylight hours (81% of crashes).

Most crashes occurred in 60km/h speed zones (69% of crashes) with 25% occurring in 80km/h speed zones and the remaining 6% in 50km/h speed zones.

The crashes in this crash group occurred most often at roundabouts at cross intersections (63%) with further crashes recorded at T-intersections (25%) and the remaining 12% at multiple / complex roundabout intersections.

3.10.4 Unsignalised Intersections

Crashes occurring at unsignalised intersections (excluding roundabouts) are generally coded as 'No Control', 'Give Way sign control' or 'Stop sign control' within the RCIS crash summaries and Police reports. While the Give Way sign and Stop sign coded crashes provide a clear indication of the intersection control, the crashes coded as 'No Control' include the following types of crashes:

- Crashes involving one vehicle turning from a priority road into a side road in the absence of traffic signals or a roundabout
- Crashes at unsignalised intersections with Give Way sign control
- Crashes at unsignalised intersections with Stop sign control

The data indicates that some crashes at Give Way sign controlled intersections are coded specifically as 'Give Way sign control', whereas similar crashes at other Give Way sign controlled intersections are coded as 'No Control'.

Similarly, some crashes at Stop sign controlled intersections are coded specifically as 'Stop sign control' whereas similar crashes at other Stop sign controlled intersections are coded as 'No Control'.

In order to accurately identify the key factors and common crash scenarios occurring at all unsignalised intersections (with the exception of roundabouts), the crashes coded 'No Control', 'Give Way sign control' and 'Stop sign control' have been considered together as one Intersection Control group for analysis.

In addition, two further sections within this report discuss crashes that have specifically been identified with Give Way sign and Stop sign control. These sections primarily address the similarities and key differences between the crash scenarios at the two types of control (Give Way sign compared with Stop sign control) at unsignalised intersections.

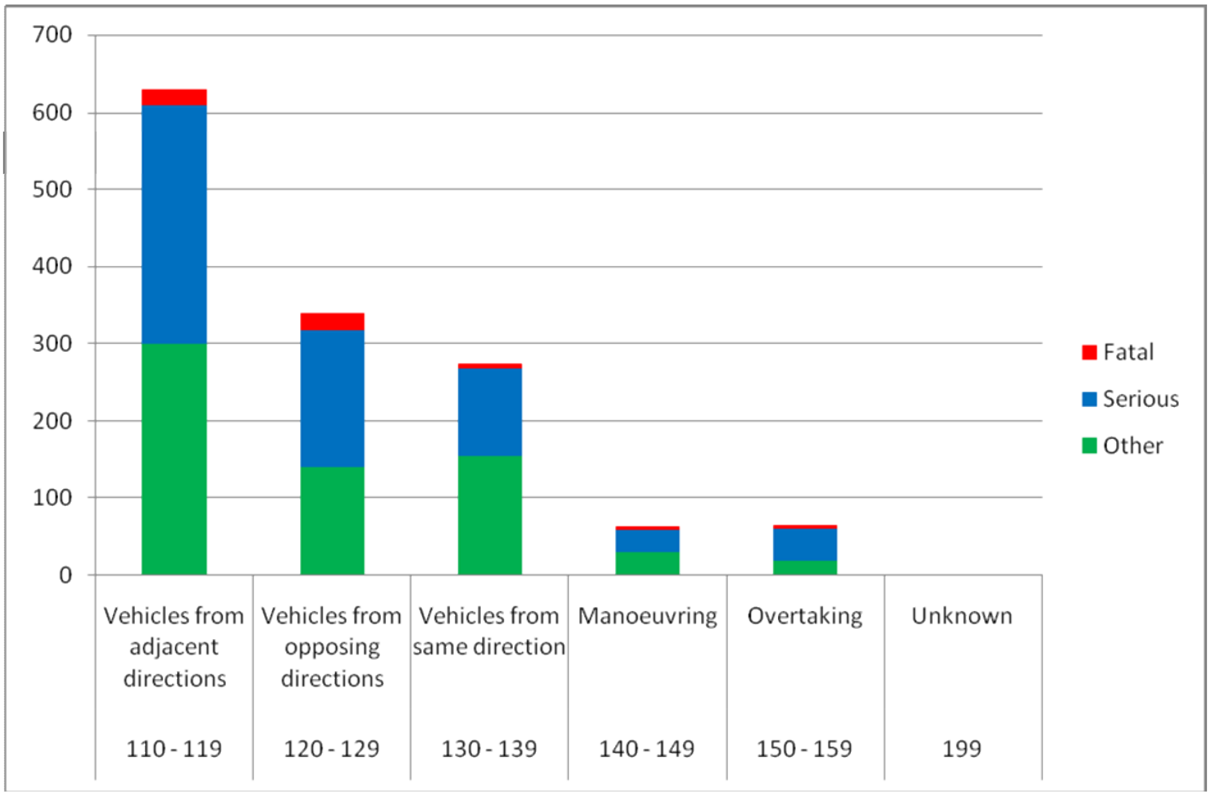
3.10.4.1 Key Crash Types

Intersections with 'No Control', Give Way sign and Stop sign control represented 65% of all motorcycle and motor scooter crashes at intersections.

The crashes over the five year period comprised 47% other injury crashes, 49% serious injury crashes and 4% fatalities.

The range of crash types are shown in Figure 41 with the source data included in Appendix A Table A41.

Figure 41: Number of casualty crashes by DCA crash group at 'No Control', Give Way sign and Stop sign control



Analysis of the data indicates the specific predominant crash types were:

- Right Through (DCA 121) crashes (24%);
- Right Near (DCA 113) crashes (24%);
- Cross Traffic (DCA 110) crashes (12%);
- Right Far (DCA 111) crashes (5%);
- Rear End type crashes including Left Rear and Right Rear (DCA 130, 131 and 132) crashes (10%);
- Lane change and side swipe (DCA 133 – 137) type crashes (10%).

The common scenarios identified within this crash group were drivers failing to give way to motorcyclists when turning at an unsignalised intersection. Crashes in dark conditions were over-represented at these locations and poor lighting may have contributed to drivers failing to recognise motorcyclists or accurately estimating motorcycle speed.

In addition, motorcyclists failing to stop before striking the rear of a vehicle were over-represented within this group. Drivers changing lanes to turn at intersections were prevalent, and motorcyclists overtaking vehicles as the vehicles performed a turn were also common scenarios.

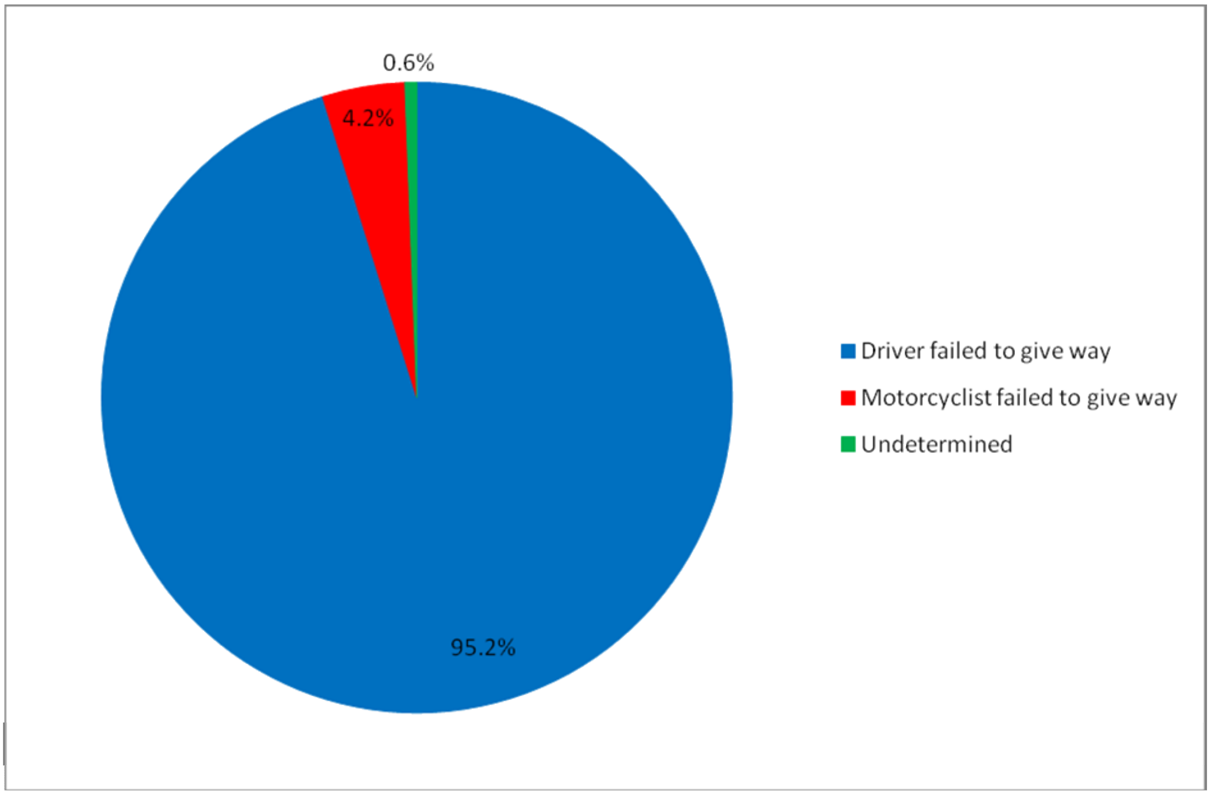
The most common crash scenarios (each representing more than 5% of crashes at 'No Control', Give Way sign and Stop sign controlled intersections) are discussed in the following sections.

3.10.4.2 Right Through Crashes

Right Through (DCA 121) crashes represented 24% of all motorcycle crashes within this intersection group. The crashes were of higher severity compared to other crash types at the same intersection type. The Right Through crashes comprised 6% fatality crashes, 53% serious injury crashes and 41% other injury crashes.

Figure 42 shows the proportion of crashes involving drivers failing to give way to motorcyclists, and motorcyclists failing to give way to opposing vehicles. The data for this graph is also included in Appendix A Table A42.

Figure 42: Proportion of crashes involving the driver and motorcyclist failing to give way during Right Through (DCA Code 121) crashes at intersections with 'No Control', Give Way sign and Stop sign control



A general assessment of the driver and motorcyclist behaviour at each of the crashes indicated over 95% of Right Through crashes involved the driver failing to give way to an approaching motorcyclist as the driver was turning right, and 4% involved the motorcyclist failing to give way. The remaining reports were unclear as to which participant failed to give way.

Analysis of the Police reports indicated motorcyclists were ‘lane splitting’ during 11% of the Right Through crashes at ‘No Control’ intersections. A further 9% were travelling in the kerbside traffic lane adjacent to queued vehicles at the time of the collision.

Vehicles were completing right turn movements using a median break in 3% of the crashes, and one crash reported the motorcyclist using the median break to turn right.

A further 1% of drivers described the motorcyclist as ‘hidden’ behind an adjacent turning vehicle or queued vehicle at the time of assessing gaps in the opposing traffic.

Almost a quarter (23%) of the Right Through crashes occurred at night in dark conditions, with a further 9% at dusk. The absence of lighting may have contributed to the collisions, and may have affected driver ability to recognize an approaching motorcyclist (with one headlight, rather than two headlights as configured on larger vehicles). In addition, the night conditions may have affected driver ability to assess the speed of approaching motorcyclists.

There was no indication of estimated speeds for the motorcyclists in any of the Police reports for Right Through crashes at ‘No Control’ intersections.

Most of the Right Through crashes occurred with a dry road surface (91%) with 9% recorded on a wet road surface.

Almost three quarters of the crashes occurred at T-intersections (74%) with 25% reported at cross intersections and the remaining 1% at multiple / complex intersections.

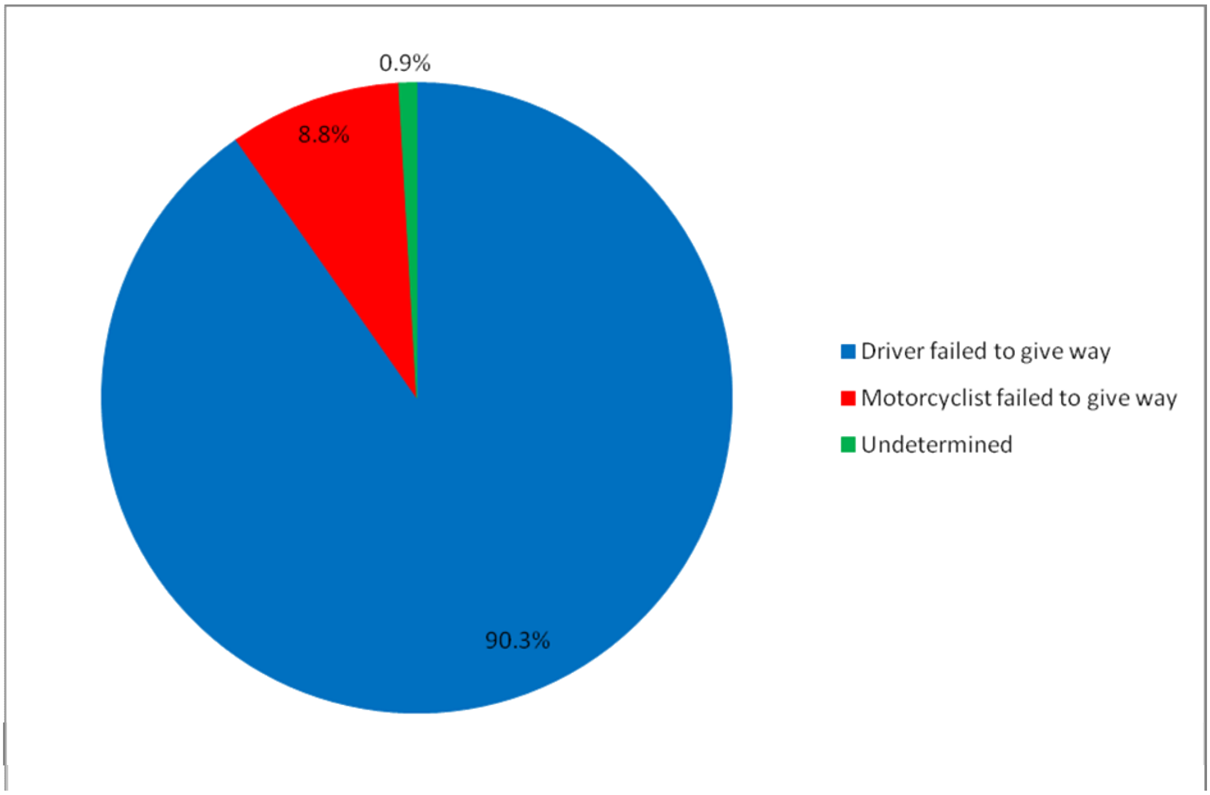
Over half of the Right Through crashes (60%) occurred in 60km/h speed with a further 24% occurring in 50km/h and 70km/h speed zones. The remaining 17% were reported in 40km/h, 80km/h, 90km/h and 100km/h speed zones.

3.10.4.3 Right Near Crashes

Right Near (DCA 113) crashes represented 24% of all motorcycle crashes at intersections with ‘No Control’, Give Way sign or Stop sign control.

Figure 43 shows the proportion of crashes involving drivers and motorcyclists failing to give way. The data for the graph is also included in Appendix A Table A43.

Figure 43: Proportion of crashes involving the driver and motorcyclist failing to give way during Right Near (DCA Code 113) crashes at intersections with 'No Control', Give Way sign and Stop sign control



A general assessment of the driver and motorcyclist behaviour at each of the crashes indicates driver behaviour (i.e. the driver failed to give way) influenced 90% of Right Near crashes.

The reports confirmed 7% of Right Near crashes occurred as a driver was turning across one carriageway to store in the central median before completing the right turn manoeuvre.

Motorcyclists were reported to be 'lane splitting' through queued traffic in 4% of Right Near crashes.

A further 1% of Right Near crashes involved motorcyclists 'hooning' or riding at night without headlights.

The Police reports confirmed drivers failed to see motorcyclists due to adjacent vehicles turning from the carriageway in 2% of collisions. Further reports indicated drivers simply 'did not see' the motorcyclist however many reports did not include clear detail of the crash to enable a clear statistical basis as to why the crash occurred.

Just under 70% of crashes occurred during the day with 18% occurring at night and 13% at dusk. The absence of lighting may have contributed to the crashes in dark conditions with drivers failing to recognize an approaching motorcyclist, or failing to accurately assess the speed of the approaching motorcyclist.

Over 80% of the crashes occurred at T-intersections with 16% recorded at cross intersections. The majority of crashes occurred in dry conditions (91%) with 9% occurring in wet weather.

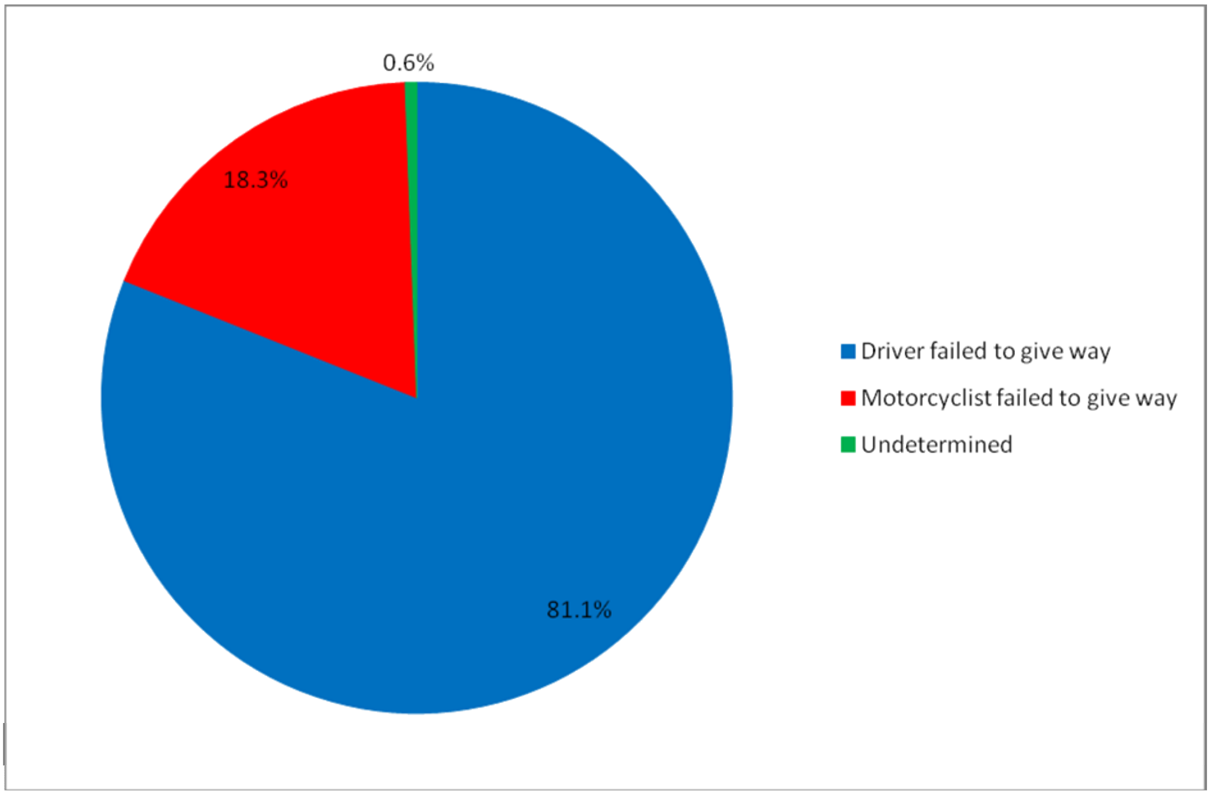
The Right Near crashes at intersections with 'No Control', Give Way sign or Stop Sign control occurred within a wide spread of speed zones. Over half of the crashes occurred in 60km/h speed zones with a further 15% in 50km/h speed zones. In addition, 11% and 12% of Right Near crashes occurred in 70km/h and 80km/h speed zones respectively and the remaining crashes occurred in 40km/h, 90km/h and 100km/h speed zones.

3.10.4.4 Cross Traffic Crashes

Cross Traffic (DCA 110) crashes represented 12% of all motorcycle crashes at 'No Control' intersections.

Figure 44 shows the proportion of crashes involving drivers and motorcyclists failing to give way. The data for the graph is also included in Appendix A Table A44.

Figure 44: Proportion of crashes involving the driver and motorcyclist failing to give way during Cross Traffic (DCA Code 110) crashes at intersections with 'No Control', Give Way sign and Stop sign control



A general assessment of the driver and motorcyclist behaviour at each of the crashes indicates driver behaviour influenced 81% of Cross Traffic crashes (i.e. the driver failed to give way).

The Police reports confirmed 5% of collisions involved drivers completing staged crossings while travelling straight across the intersection. Insufficient details were provided in the Police reports to enable a clear assessment of other contributing factors to the Cross Traffic crashes at 'No Control', Give Way sign and Stop sign controlled intersections.

Almost three quarters (72%) of crashes occurred during the day with 15% at night and 13% at dusk. The absence of lighting may have contributed to the crashes in dark conditions with drivers failing to recognize an approaching motorcyclist, or failing to accurately assess the speed of the approaching motorcyclist.

Over 97% of the crashes occurred at cross intersections and the majority of crashes occurred in dry weather (92%) with 7% reported on a wet road surface.

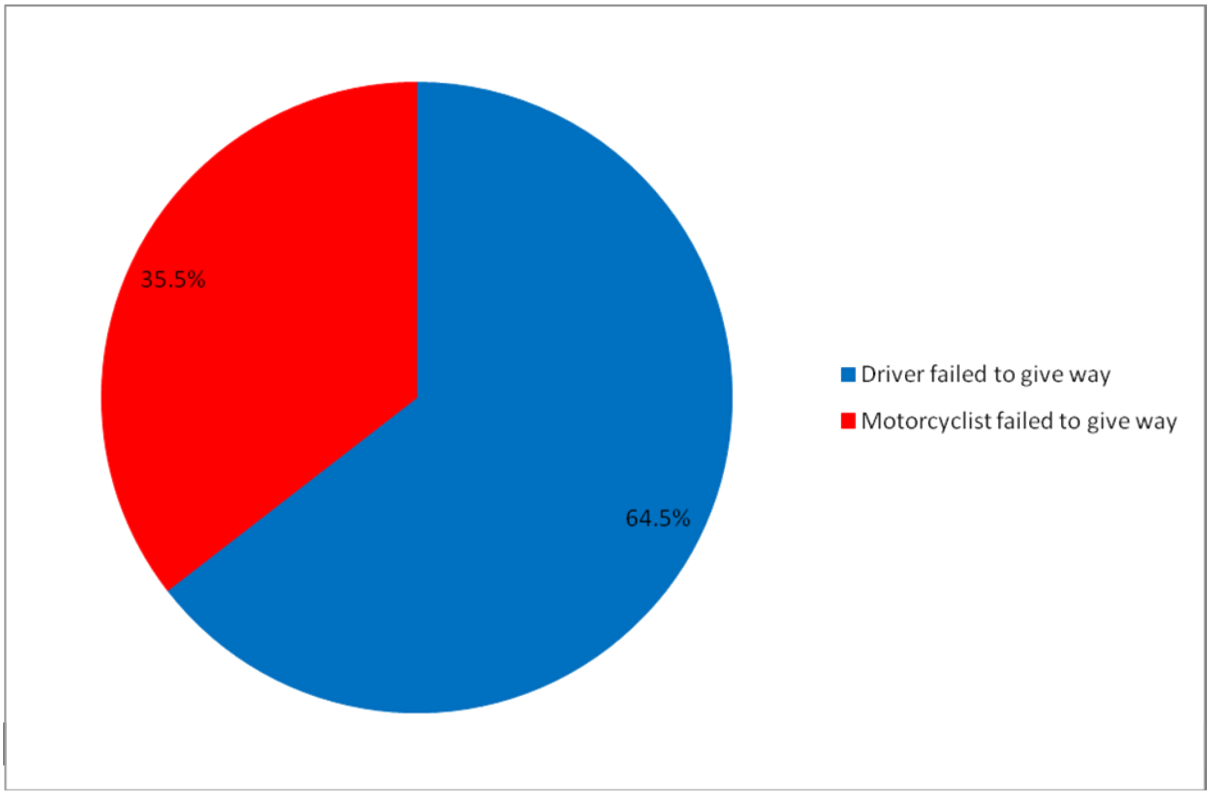
A higher proportion of crashes (30%) were reported in 50km/h speed zones, with 52% occurring in a 60km/h speed zone. The remaining crashes occurred in speed zones between 40km/h and 100km/h.

3.10.4.5 Right Far Crashes

Right Far (DCA 111) crashes represented 5% of all motorcycle crashes at 'No Control', Give Way sign and Stop sign controlled intersections.

Figure 45 shows the proportion of crashes involving drivers and motorcyclists failing to give way. The data for the graph is also included in Appendix A Table A45.

Figure 45: Proportion of crashes involving the driver and motorcyclist failing to give way during Right Far (DCA Code 111) crashes at intersections with 'No Control', Give Way sign and Stop sign control



A general assessment of the driver and motorcyclist behaviour at each of the crashes indicates a higher proportion of motorcyclist-related errors compared to other crash types and intersection controls. Motorcyclist behaviour led to 35% of the Right Far crashes reported with the main factor involving motorcyclists failing to give way to approaching vehicles, turning right at intersections with banned right turns and travelling at excessive speed.

Drivers failed to give way to motorcyclists approaching from the left as the driver was turning right in 65% of Right Far crashes.

Over 11% of collisions involved the driver using the median break to perform a staged crossing and a further 3% involved the motorcyclist attempting the staged crossing.

Motorcyclists were 'lane splitting' between queued vehicles in 5% of crashes and motorcyclists were travelling in the kerbside lane adjacent to queued vehicles in a further 2% of collisions.

Over a quarter (26%) of crashes occurred during dark (night) conditions with 11% occurring at dusk. The absence of lighting may have contributed to the crashes in dark conditions with drivers failing to recognize an approaching motorcyclist, or failing to accurately assess the speed of the approaching motorcyclist.

Two thirds (66%) of the Right Far crashes occurred at T-intersections with 31% occurring at cross intersections and the remaining 3% occurring at multiple / complex intersections.

Over 90% of Right Far crashes occurred in dry weather with 7% reported with a wet road surface.

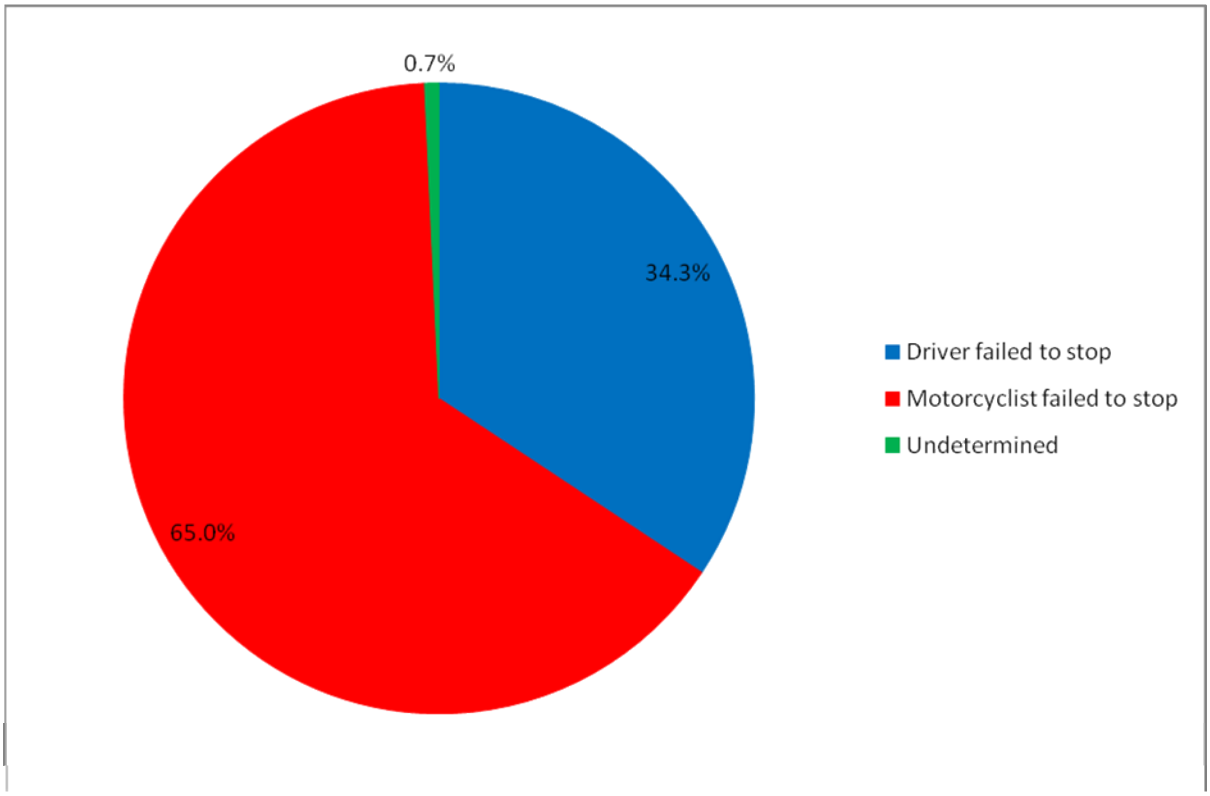
Approximately 52% of Right Far crashes at 'No Control' intersections occurred in 60km/h speed and over 20% in 80km/h speed zones. The remaining crashes occurred in 40km/h – 110km/h speed zones.

3.10.4.6 Rear End Type Crashes

Rear end type crashes including Rear End (DCA 130), Left Rear (DCA 131) and Right Rear (DCA 132) crashes represented 10% of all motorcycle crashes at 'No Control' intersections.

Figure 46 shows the proportion of crashes involving drivers and motorcyclists failing to give way. The data for the graph is also included in Appendix A Table A46.

Figure 46: Proportion of crashes involving the driver and motorcyclist failing to stop during rear end type (DCA Code 130, 131 and 132) crashes at 'No Control', Give Way sign and Stop sign controlled intersections



A general assessment of the driver and motorcyclist behaviour at each of the crashes indicates a higher proportion of motorcyclist-related errors compared to other crash types and intersection controls. Motorcyclist behaviour led to 65% of the rear end type crashes reported and the Police reports confirmed over 10% of crashes occurred with the vehicle stationary at the stopline of the intersection before the motorcyclist struck the vehicle.

While Right Rear (DCA 132) crashes represent 43% of this group of crashes, a further 2% of Rear End (DCA 130) crashes occurred as vehicles or motorcyclists changed lanes to avoid a right turning vehicle propped in the right lane, and consequently struck the rear of a vehicle in the adjacent traffic lane.

Over 90% of crashes occurred in dry conditions with 7% reported on a wet road surface.

Over 78% of crashes occurred during daylight hours with 12% in dark conditions at night and 10% at dusk.

Over 70% of rear end type crashes occurred at T-intersections with 27% at cross intersections.

Approximately 55% of rear end type crashes at 'No Control' intersections occurred in 60km/h speed zones and 23% in 70km/h and 80km/h speed zones combined. The remaining crashes occurred in 40km/h, 50km/h and 100km/h speed zones.

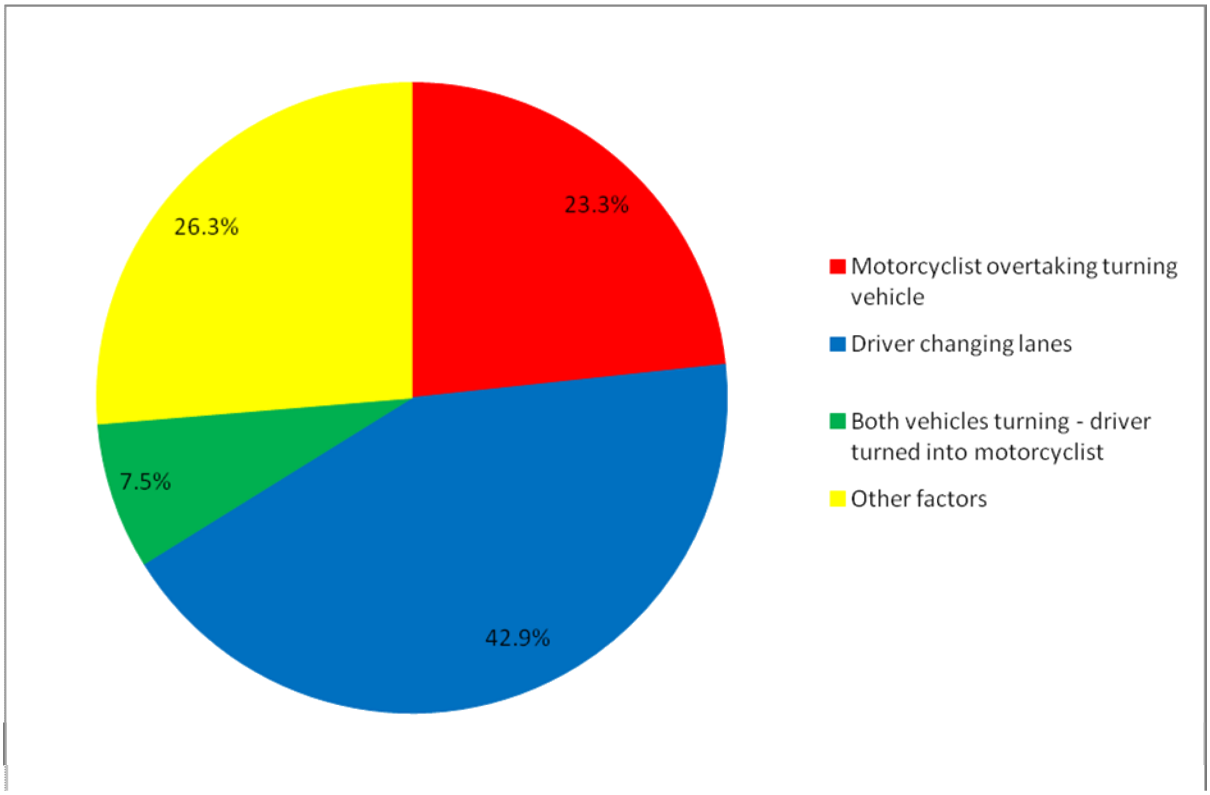
3.10.4.7 Lane Change and Side Swipe Type Crashes

Lane change and side swipe type crashes including Lane Side Swipe (DCA 133), Lane Change Right (DCA 134), Lane Change Left (DCA 135), Right Turn Side Swipe (DCA 136) and Left Turn Side Swipe (DCA 137) crashes represented 10% of all motorcycle crashes at intersections with 'No Control', Give Way sign and Stop sign control.

A general assessment of the driver and motorcyclist behaviour at each of the crashes indicates a higher proportion of motorcyclist-related errors compared to other crash types and intersection controls. Motorcyclist behaviour led to 36% of the lane change and side swipe types crashes reported with driver behaviour contributing to 59% of crashes. The details of a further 5% of crashes were unclear.

Figure 47 shows some of the key factors involved in these type of crashes. The data for this graph is included in Appendix A Table A47.

Figure 47: Common crash scenarios in lane change and side swipe type crashes at intersections with 'No Control', Give Way sign and Stop sign control



Over 42% of crashes involved drivers changing lanes into a traffic lane with a motorcyclist present. Lane changes to the left represented 32% of collisions while lane changes to the right represented the remaining 10%. Drivers were attempting to avoid vehicles propped to turn right in 7% of the collisions involving drivers changing lanes to the left.

Almost a quarter of collisions (23%) occurred as a motorcyclist was attempting to overtake a vehicle and the vehicle turned into a side street. Approximately half of the collisions involved a vehicle turning left and half involved a vehicle turning right.

Just under 7% of crashes involved both the motorcyclist and vehicle turning at an intersection and colliding during the turn. The majority of these crashes (89%) involved both participants attempting to turn left.

Over 90% of crashes occurred in dry conditions with 8% reported on a wet road surface.

Over 78% of crashes occurred during daylight hours with 11% in dark conditions at night and 11% at dusk.

Over 70% of rear end type crashes occurred at T-intersections with 23% at cross intersections.

Approximately 59% of lane change and side swipe type crashes at intersections with 'No Control', Give Way sign and Stop sign control occurred in 60km/h speed zones and 12% in both 50km/h and 80km/h speed zones. The remaining crashes occurred in 40km/h, 70km/h and 90km/h and 100km/h speed zones.

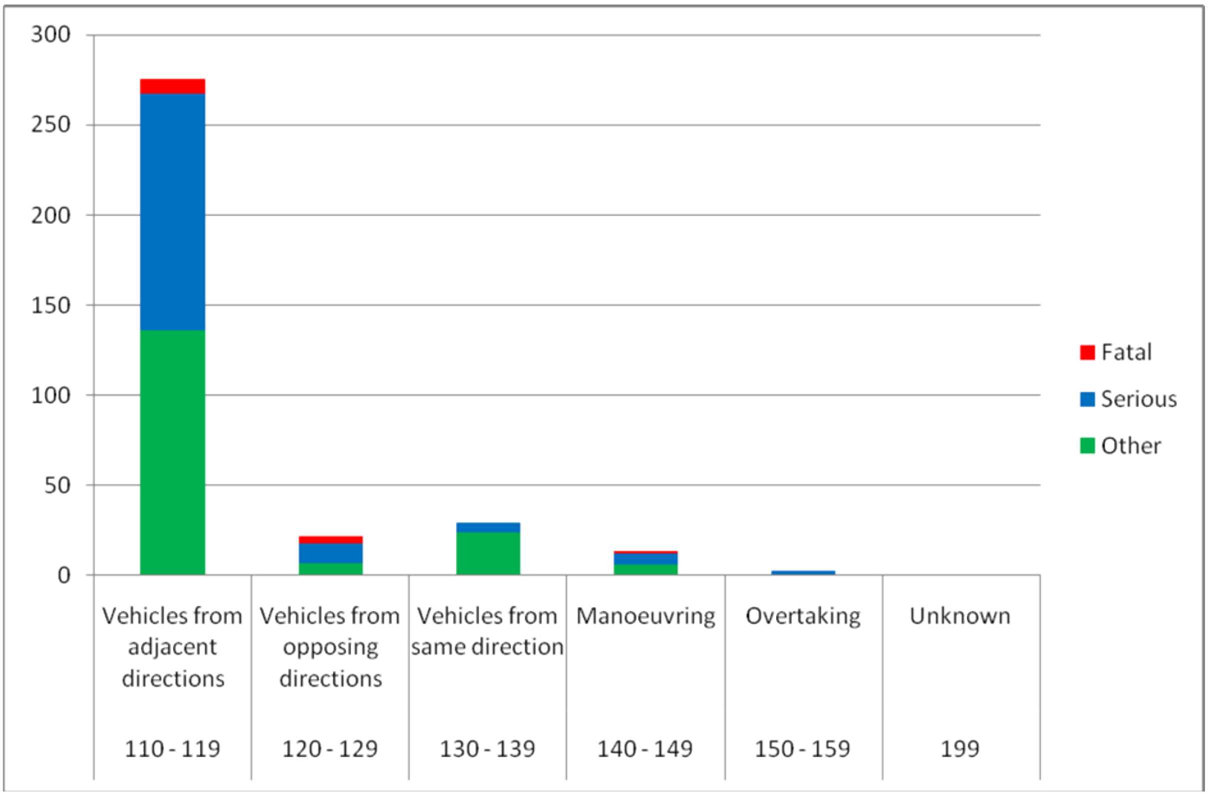
3.10.5 Give Way Sign

Crashes specifically identified as occurring at Give Way sign controlled intersections have been analysed separately to determine key factors specific to Give Way sign control.

Crashes identified at Give Way sign controlled intersections represented 16% of all motorcycle intersection crashes. The severity of crashes at Give Way sign controlled intersections were slightly lower than for the entire 'No Control' group of crashes (which included both Give Way sign and Stop sign control), and comprised 51% other injury crashes, 45% serious injury crashes and 3% fatalities.

The range of crash types are shown in Figure 48 with the source data included in Appendix A Table A48.

Figure 48: Number of casualty crashes by DCA crash group at intersection with Give Way sign control



The crashes specifically recorded at Give Way sign controlled intersections included a higher proportion of crashes involving vehicles approaching from adjacent directions (DCA 110 – 119) compared with the complete set of crashes occurring at 'No Control', Give Way sign and Stop sign controlled intersections.

The specific key crash types were Cross Traffic (DCA 110) crashes, Right Far (DCA 111) crashes, Right Near (DCA 113) crashes and Left Near (DCA 116) crashes together representing 77% of crashes at Give Way sign controlled intersections. In addition, Right Through (DCA 121) crashes represented a further 6% of crashes.

The predominant patterns within each of the crashes was drivers failing to give way to motorcyclists and a higher proportion of crashes occurring in dark (night) conditions compared with other intersection control types.

The absence of lighting at the intersection may have contributed to drivers failing to recognize the presence or speed of approaching motorcyclists at the intersections.

3.10.5.1 Right Near Crashes

Right Near (DCA 113) crashes represented 44% of all motorcycle crashes at Give Way sign controlled intersections. The characteristics of the Right Near crashes were generally consistent with the findings for the 'No Control' group of crashes.

A general assessment of the driver and motorcyclist behaviour at each of the crashes indicates driver behaviour influenced the same proportion of Right Near crashes as for the 'No Control' group of crashes.

The reports confirmed 11% of collisions involved drivers completing staged crossings while performing the right turn.

As per the findings for the 'No Control' intersections, the Police reports described a number of driver accounts that 'didn't see' the motorcyclist and in particular, 3% of drivers identified a vehicle turning in front of the approaching motorcyclist restricted their visibility of the motorcycle. In addition, the reports confirmed 3% of crashes involved motorcyclists 'lane splitting' between queued vehicles. The overall detail within the Police reports did not provide a clear statistical basis for the exact reasons of the remaining collisions.

The light conditions at the time of the crashes were identical to the complete 'No Control' group of crashes (70% during the day and 18% at night) and the high proportion of crashes at T-intersections (80%) were also consistent with the 'No Control' group.

As per the 'No Control' group, the majority of crashes occurred in dry conditions (89%) with 11% occurring in wet weather.

Similarly with the 'No Control' group, over 50% of Right Near crashes at Give Way sign controlled intersections occurred in 60km/h speed zones with a further 18% in 50km/h speed zones, and 25% in 70km/h and 80km/h speed zones combined.

3.10.5.2 Cross Traffic Crashes

Cross Traffic (DCA 110) crashes represented 20% of all motorcycle crashes at Give Way sign controlled intersections. A general assessment of the driver and motorcyclist behaviour at each of the crashes indicates driver behavior influenced 81% of Cross Traffic crashes which is consistent with the 'No Control' group of crashes.

The Police reports indicated a higher proportion (9%) of collisions involved drivers completing staged crossings while travelling straight across the intersection compared with the 'No Control' group.

The Police reports confirmed 3% of collisions involved motorcyclists 'lane splitting' or travelling in the kerbside lane adjacent to queued vehicles. Only one driver reported visibility to the motorcyclist was restricted by a vehicle turning in front of the motorcycle.

Similar to the 'No Control' group, three quarters (75%) of crashes occurred during the day with 12% at night and 13% at dusk. The absence of lighting may have contributed to the crashes in dark conditions with drivers failing to recognize an approaching motorcyclist, or failing to accurately assess the speed of the approaching motorcyclist.

The speed zones, geometry of the intersection and weather conditions during the crashes were consistent with the 'No Control' group of crashes.

3.10.5.3 Left Near Crashes

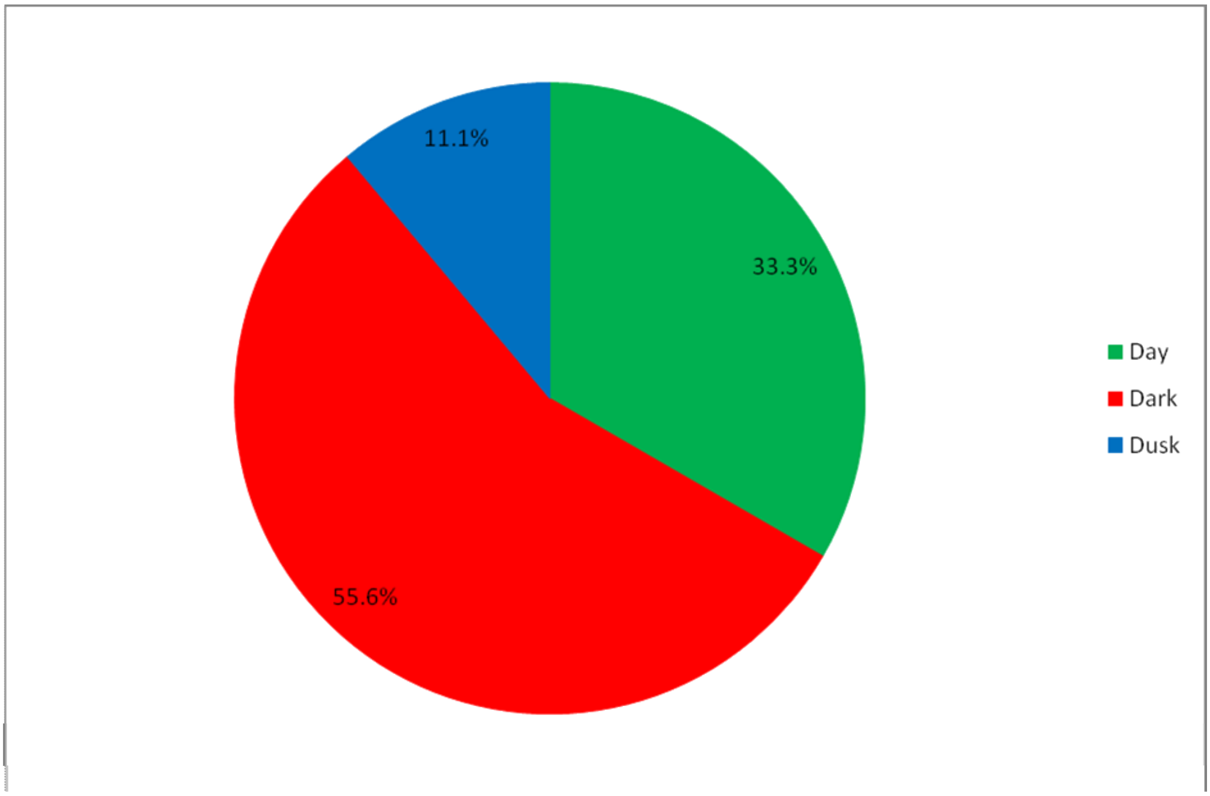
Left Near (DCA 116) crashes represented 5% of all motorcycle crashes at Give Way sign controlled intersections which is a higher proportion than the complete 'No Control' group of crashes.

A general assessment of the driver and motorcyclist behaviour at each of the crashes indicates 89% of this type of crashes of this type involved the driver failing to give way to an approaching motorcyclist as the driver was turning left. A further 6% confirmed the motorcyclist failed to give way and 6% were unclear as to which participant's behaviour led to the collision.

Over 10% of crashes occurred as a driver was entering the centre carriageway from the service road on a primary arterial road.

The light conditions at the time of the crash are shown in Figure 49 with the data included in Appendix A Table A49.

Figure 49: Light conditions during Left Near (DCA Code 116) crashes at Give Way sign controlled intersections



Over 55% of crashes occurred during dark (night) conditions which is significantly higher than other crash types. This suggests the absence of lighting may have contributed to the crashes with drivers failing to recognize an approaching motorcyclist, or failing to accurately assess the speed of the approaching motorcyclist.

A Police report identified the motorcyclist exceeding the speed limit at one of the collisions. An estimate of motorcycle speed was not included in the Police reports at the remaining crashes.

Over 75% of Left Near crashes occurred at T-intersections with 17% occurring at cross intersections and 6% at Y-intersections.

The majority of crashes occurred in dry weather (83%) with 11% occurring on a wet road surface.

Half of the Left Near crashes at Give Way sign controlled intersections occurred in 60km/h speed zones with 28% recorded in 80km/h speed zones and the remaining crashes occurring in 50km/h and 70km/h zones.

3.10.5.4 Right Far Crashes

Right Far (DCA 111) crashes represented 8% of all motorcycle crashes at Give Way sign controlled intersections.

A general assessment of the driver and motorcyclist behaviour at each of the crashes indicated the proportion of drivers failing to give way to a motorcyclist approaching from the left was consistent with the findings for the 'No Control' group.

Over a fifth of crashes (22%) involved the driver of a vehicle completing a staged crossing when the collision occurred which is a considerably higher proportion than the general 'No Control' group. A further 4% of crashes involved the motorcyclist attempting the staged crossing.

A third (33%) of crashes occurred during dark (night) conditions which is higher than the 'No Control' group, and a further 11% of crashes occurred at dusk. The absence of lighting may have contributed to the crashes in dark conditions with drivers failing to recognize an approaching motorcyclist, or failing to accurately assess the speed of the approaching motorcyclist.

The weather conditions and intersection geometry was generally consistent with the 'No Control' group.

Approximately 48% of Right Far crashes at Give Way sign controlled intersections occurred in 60km/h speed and nearly a third (30%) in 80km/h speed zones. The remaining crashes occurred in 50km/h, 70km/h and 100km/h speed zones.

3.10.5.5 Right Through Crashes

Right Through (DCA 121) crashes represented 6% of all motorcycle crashes at Give Way sign controlled intersections and the findings were generally similar to the 'No Control' group.

A general assessment of the driver and motorcyclist behaviour at each of the crashes indicates 90% of Right Through crashes involved the driver failing to give way to an approaching motorcyclist as the driver was turning right, and 10% involved the motorcyclist failing to give way.

Motorcyclists were reported to be 'lane splitting' during 15% of the Right Through crashes, and travelling in the kerbside lane adjacent to queued vehicles in 10% of the collisions.

The majority of Right Through crashes occurred during the day (90%) and in dry weather conditions (95%). Most crashes (70%) occurred at T-intersections with 30% reported at cross intersections.

Half of the Right Through crashes (50%) occurred in 60km/h speed and the remaining crashes occurred in 50km/h, 70km/h, 80km/h and 100km/h speed zones.

3.10.6 Stop Sign

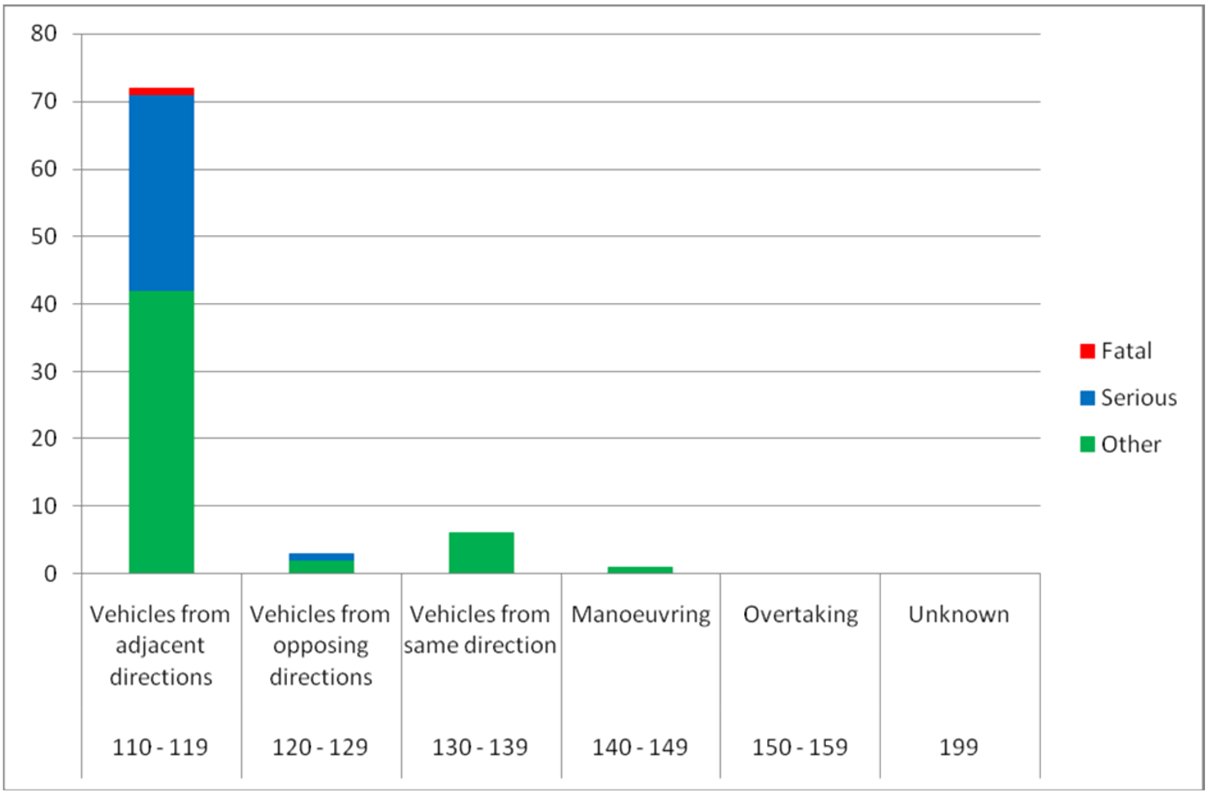
The installation of a Stop sign is intended to ensure drivers (and motorcyclists) come to a complete stop before entering an intersection. The current warrants for the installation of Stop signs restrict their implementation to intersections with restricted sight distance on the approach to the intersection. The installation of Stop signs at these locations ensures drivers (and motorcyclists) decelerate and stop at a position where sight distance is adequate for the driver or rider to assess gaps in the approaching traffic. It is acknowledged, however, that there are Stop signs currently installed within the road network where this warrant is not presently met (i.e. there is adequate sight distance on the approach to the intersection and the intersection could be adequately controlled with a Give Way sign rather than a Stop sign).

There were 116 motorcycle crashes specifically recorded at intersections with Stop signs during the five year period which represents 6% of the total number of motorcycle intersections crashes.

The crashes were generally of a lower severity compared to the complete 'No Control' group, and compared to the Give Way sign controlled group, and comprised 54% other injury crashes, 45% serious injury crashes and 1% were fatalities. This may be due to lower speeds of vehicles and motorcyclists entering the intersection from the stopline.

The range of crash types are shown in Figure 50 with the source data included in Appendix A Table A50.

Figure 50: Number of casualty crashes by DCA crash group at Stop sign controlled intersections



The patterns for crashes at Stop sign controlled intersections were very similar to those specifically identified at Give Way sign controlled intersections. The most common crash scenarios involved vehicles approaching from adjacent directions which represented 91% of crashes.

Within these crash groups, the common types of crashes were Right Near (DCA 113) crashes, Cross Traffic (DCA 110) crashes, Left Near (DCA 116) crashes and Right Far (DCA 111) crashes.

The remaining 9% of motorcycle crashes at Stop sign controlled intersections involved a mix of Right Through (DCA 121) crashes , rear end (DCA 130 – 132) type crashes, side swipe (DCA 136 – 137) type crashes and an Emerging from Driveway / Laneway (DCA 147) type crash.

The predominant patterns within each of the crashes were drivers failing to give way to motorcyclists and a higher proportion of crashes occurring in dark (night) conditions compared with other intersection control types.

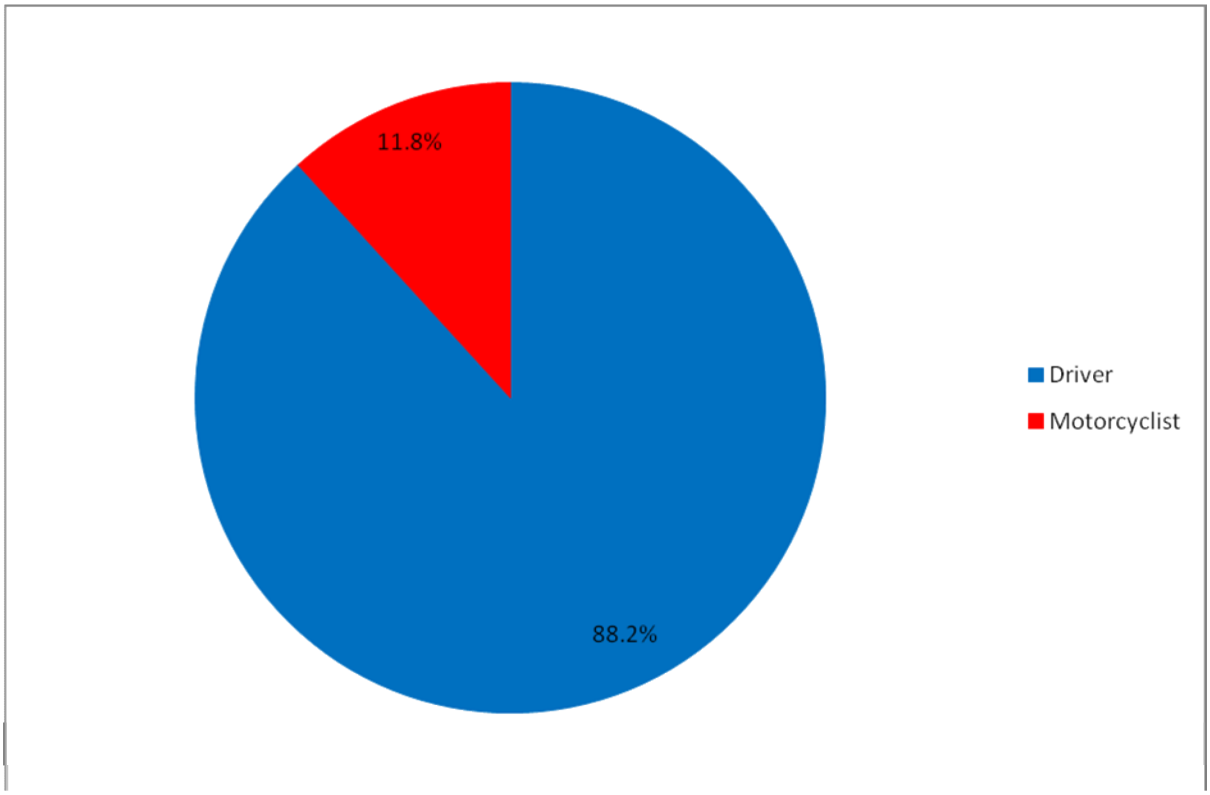
The absence of lighting at the intersection and drivers failing to recognize the presence or speed of approaching motorcyclists may have been key contributing factors to the crashes.

3.10.6.1 Right Near Crashes

Right Near (DCA 113) crashes represented the same proportion (44%) of all motorcycle crashes at Stop Sign controlled intersections as with Give Way sign controlled intersections.

Figure 51 shows the proportion of crashes involving drivers and motorcyclists failing to give way. The data for the graph is also included in Appendix A Table A51.

Figure 51: Proportion of crashes involving the driver and motorcyclist failing to give way during Right Near (DCA code 113) crashes at Stop sign controlled intersections



A general assessment of the driver and motorcyclist behaviour at each of the crashes indicates driver behaviour influenced 88% of Right Near crashes which is slightly lower than the 'No Control' and Give Way sign controlled groups of crashes.

The reports confirmed 4% of collisions involved drivers completing staged crossings while performing the right turn which is lower than the findings for Give Way sign controlled intersections.

The Police reports indicated a number of driver accounts that they 'didn't see' the motorcyclist however the detail within the remaining Police reports did not provide a clear statistical basis for the exact reasons for the collisions.

Over 70% of crashes occurred during the day with 12% at night and 18% at dusk which is generally consistent with the 'No Control' and Give Way sign control groups. The absence of lighting may have contributed to the crashes in dark conditions with drivers failing to recognize an approaching motorcyclist, or failing to accurately assess the speed of the approaching motorcyclist.

Over 70% of the crashes occurred at T-intersections which is slightly lower than the 'No Control' and Give Way sign control groups.

Consistent with the 'No Control' and Give Way sign control groups, the majority of crashes occurred in dry conditions (88%) with 12% occurring in wet weather.

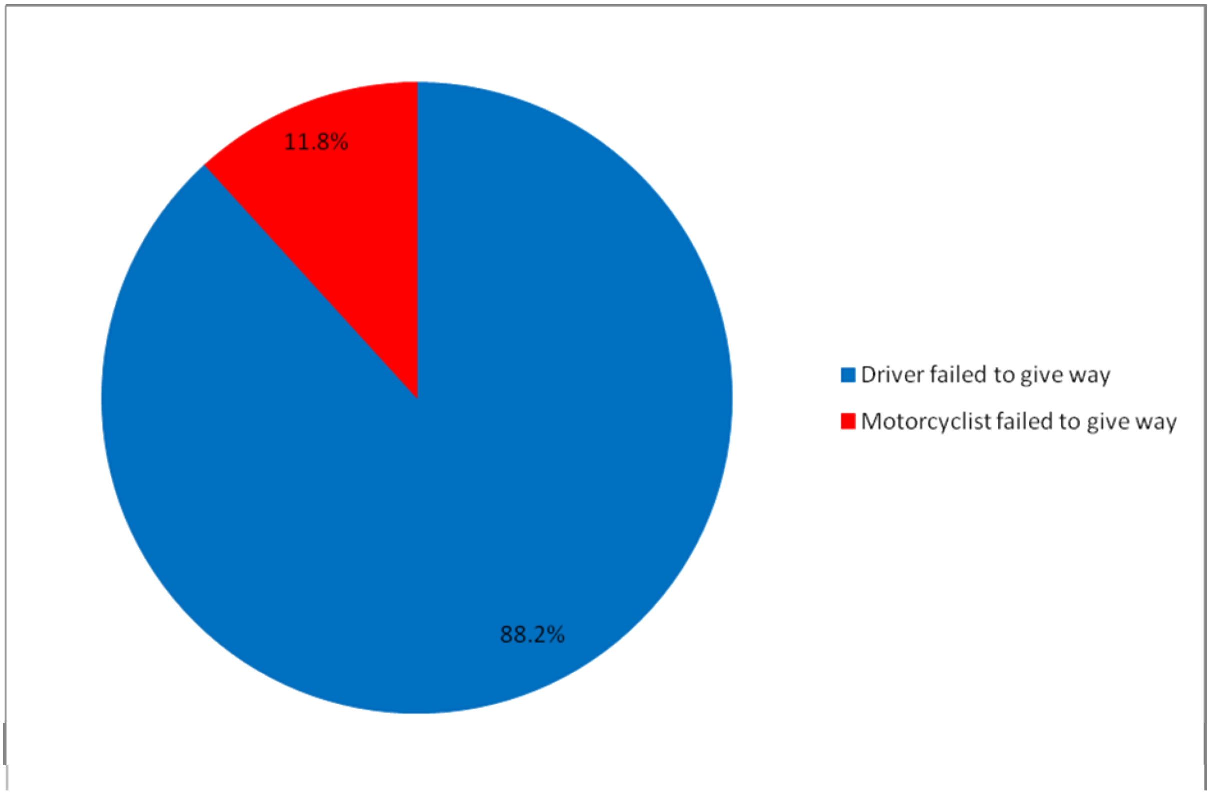
A higher proportion of Right Near crashes (over 70%) occurred in 60km/h speed zones compared with the 'No Control' and Give Way sign control groups. A further 24% of crashes occurred in 50km/h and 70km/h speed zones combined.

3.10.6.2 Cross Traffic Crashes

Cross Traffic (DCA 110) crashes represented 29% of all motorcycle crashes at Stop Sign controlled intersections which is a higher proportion than at 'No Control' and Give Way sign controlled intersections.

Figure 52 shows the proportion of crashes involving drivers and motorcyclists failing to give way. The data for the graph is also included in Appendix A Table A52.

Figure 52: Proportion of crashes involving the driver and motorcyclist failing to give way during Cross Traffic (DCA Code 110) crashes at Stop sign controlled intersections



A general assessment of the driver and motorcyclist behaviour at each of the crashes indicates driver behaviour influenced the same proportion (88%) of Cross Traffic crashes as Right Near crashes at Stop sign controlled intersections.

The reports confirmed the same proportion of crashes involved drivers completing staged crossings while travelling straight across the intersection as with the Give Way sign controlled intersections. This proportion is higher than the staged crossings confirmed in Right Near crashes.

The Police reports indicated a number of driver accounts that they 'didn't see' the motorcyclist however the detail within the complete set of Police reports did not provide a clear statistical basis for the exact reasons of the collisions.

A higher proportion of Cross Traffic crashes occurred during the day (80%) compared with the 'No Control' group and Give Way sign control intersections.

All of the crashes occurred at cross intersections and the majority of crashes occurred in dry weather (94%) with 3% occurring on a wet road surface.

Over 60% of Cross Traffic crashes at Stop sign controlled intersections occurred in 60km/h speed zones which is slightly higher than the 'No Control' and Give Way sign controlled intersections. A further 24% of crashes occurred in 50km/h speed zones.

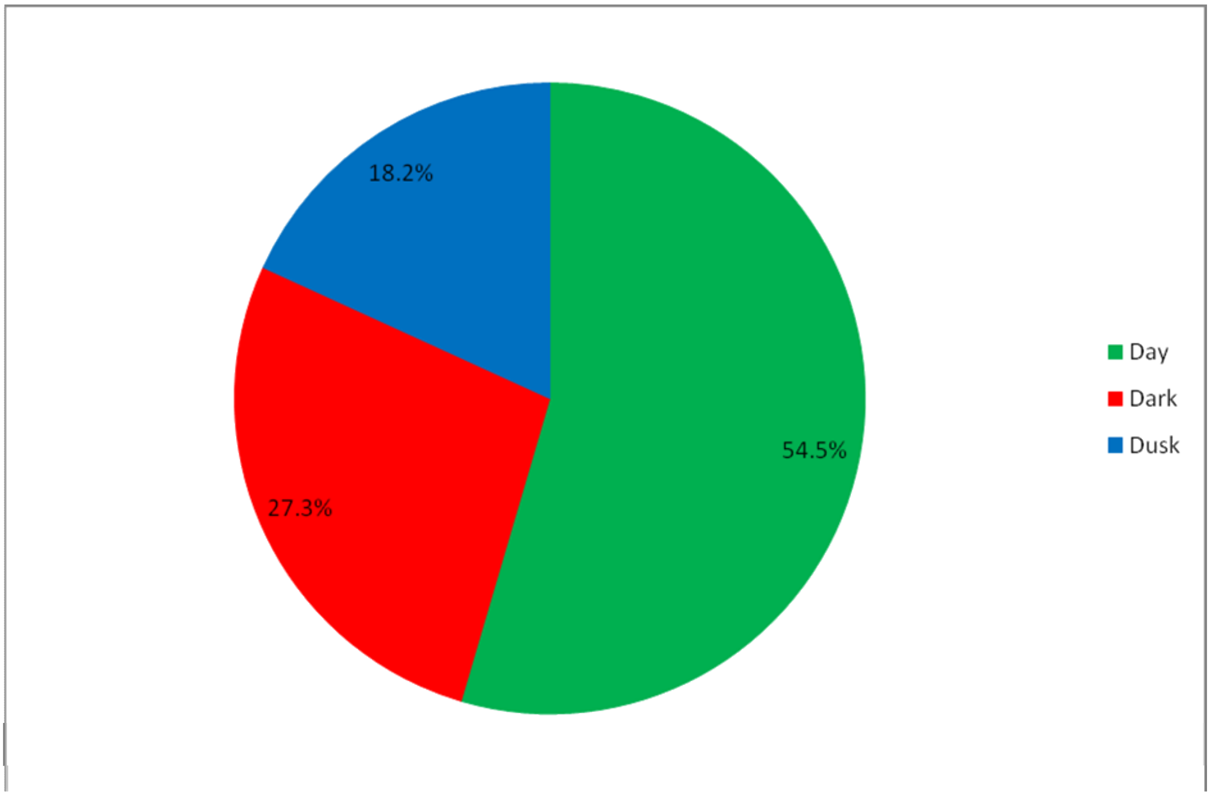
3.10.6.3 Left Near Crashes

Left Near (DCA 116) crashes represented 9% of all motorcycle crashes at Stop Sign controlled intersections which is considerably higher than the proportion of Left Near crashes within the 'No Control' group.

The analysis indicates all crashes of this type involved the driver failing to give way to an approaching motorcyclist as the driver was turning left.

The light conditions at the time of the crashes are shown in Figure 53 with the data for the graph also included in Appendix A Table A53.

Figure 53: Light conditions during Left Near (DCA Code 116) crashes at Stop sign controlled intersections



Over 45% of crashes occurred during dark (night) conditions or at dusk (combined) which is significantly higher than other crash types and generally consistent with the Left Near crashes at Give Way sign controlled intersections. The absence of lighting may have contributed to the crashes in dark conditions with drivers failing to recognize an approaching motorcyclist, or failing to accurately assess the speed of the approaching motorcyclist.

Over 80% of Left Near crashes occurred at T-intersections which is slightly higher than the findings for Give Way sign controlled intersections.

The majority of crashes occurred in dry weather (91%) with 9% occurring on a wet road surface which is generally consistent with the findings at Give Way sign controlled intersections.

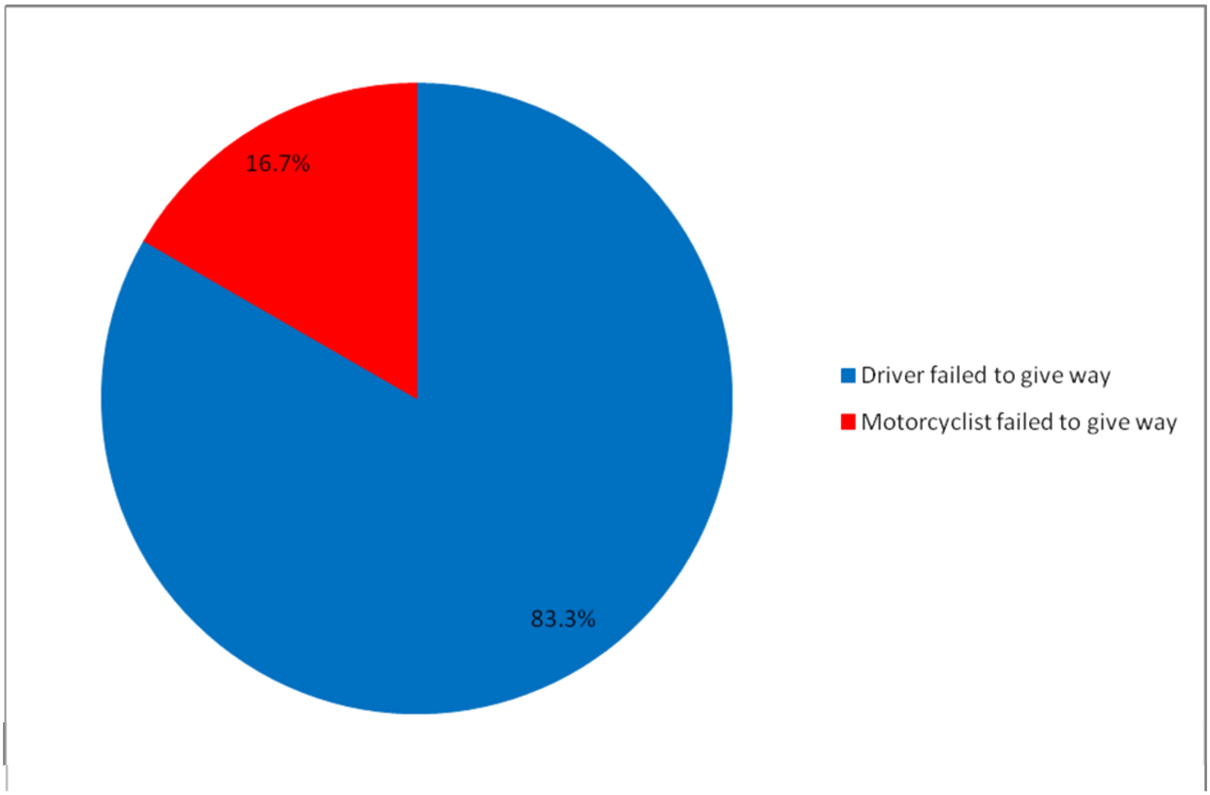
Over 60% of Left Near crashes at Stop sign controlled intersections occurred in 60km/h speed zones with the remaining crashes occurring in 50km/h, 70km/h and 80km/h speed zones.

3.10.6.4 Right Far Crashes

Right Far (DCA 111) crashes represented 5% of all motorcycle crashes at Stop Sign controlled intersections.

Figure 54 shows the proportion of crashes involving drivers and motorcyclists failing to give way. The data for the graph is also included in Appendix A Table A54.

Figure 54: Proportion of crashes involving the driver and motorcyclist failing to give way during Right Far (DCA Code 111) crashes at Stop sign controlled intersections



A general assessment of the driver and motorcyclist behaviour at each of the crashes indicates over 80% of Right Far crashes involved the driver failing to give way to a motorcyclist approaching from the left as the driver was turning right. This is inconsistent with the findings for the 'No Control' group and the Give Way sign controlled intersections, at which locations motorcyclist-related errors represented a higher proportion of crashes.

The absence of motorcyclist errors at the Stop sign locations may be due to rider behaviour with motorcyclists recognising the requirement to stop and assess gaps before continuing into the intersection.

A third (33%) of crashes occurred during dark (night) conditions or at dusk which is consistent with the Give Way sign controlled intersections. The absence of lighting may have contributed to the crashes in dark conditions with drivers failing to recognize an approaching motorcyclist, or failing to accurately assess the speed of the approaching motorcyclist.

Half of the Right Far crashes occurred at T-intersections with a third (33%) occurring at cross intersections and the remaining 17% occurring at multiple / complex intersections. All Right Far crashes were reported in dry weather.

A third of the Right Far crashes at Stop sign controlled intersections occurred in 60km/h speed zones which is less than the findings for the 'No Control' group and Give Way sign controlled intersections. A further third of crashes occurred in 50km/h speed zones which is greater than the proportion of crashes at 'No Control' and Give Way sign controlled intersections. The remaining crashes occurred in 70km/h and 80km/h speed zones.

4 SUMMARY OF KEY CHARACTERISTICS

4.1 Intersection Geometry

The findings for the key crash characteristics by intersection geometry are summarised in Table 1.

Table 1 shows the key crash characteristics for cross intersections, T-intersections and multiple / complex intersections compared with the overall average for all intersection geometry types. Y-intersections are omitted from the table due to the low number of motorcycle crashes occurring at these locations (10 crashes in the 5 year period).

The table shows the total number of crashes for each intersection geometry type, and includes the severity of crashes and the proportion of crashes occurring in varying weather and lighting conditions. The intersection control and the participant behaviour are included in the table, in addition to the crash types representing more than 5% of intersection crashes.

Table 1: Summary of Crash Statistics by Intersection Geometry

Characteristic		Cross Intersections	T-Intersections	Multiple / Complex Intersections	All Intersections
Number of crashes in 5 year period		959 (46%)	1071 (51%)	64 (3%)	2104
Crash Severity	Fatality	2%	4%	2%	3%
	Serious Injury	47%	47%	48%	47%
	Other Injury	51%	49%	50%	50%
Weather	Wet	8%	8%	6%	8%
	Dry	91%	91%	94%	91%
Light	Day	68%	70%	67%	69%
	Dusk	12%	10%	11%	11%
	Dark	20%	20%	22%	20%
Behaviour	Vehicle Driver	79%	74%	80%	76%
	Motorcycle Rider	19%	24%	20%	22%
	Undetermined	2%	2%	N/A	2%
Predominant Crash Types	Cross Traffic (DCA 110)	**30%**	N/A	**23%**	14%
	Right Far (DCA 111)	3%	4%	6%	4%
	Right Near (DCA 113)	8%	**27%**	13%	18%
	Left Near (DCA 116)	2%	4%	5%	3%
	Right Through (DCA 121)	**31%**	**28%**	**20%**	29%
	Rear End (DCA 130 – 132)	11%	12%	8%	12%
	Lane Change & Side Swipe (DCA 133 – 137)	10%	11%	**20%**	11%
	Pulling Out (DCA 152)	1%	5%	2%	3%
Intersection Control	Traffic Signals	41%	12%	48%	26%
	Roundabouts	15%	2%	20%	9%
	Unsignalised Intersections	44%	86%	31%	65%

Table 1 summarises the information discussed in Section 3 of this report and the following key findings are noted:

- The characteristics of motorcycle crashes at cross intersections and T-intersections are very similar and differ notably by intersection control type only
- Crashes at cross intersections were predominantly Right Through (DCA 121) crashes and Cross Traffic (DCA 110) crashes
- Crashes at T-intersections were predominantly Right Through (DCA 121) crashes and Right Near (DCA 113) crashes. The proportion of Right Near crashes at T-intersections was higher than the average proportion of Right Near crashes at all intersection geometry types
- Crashes at multiple / complex intersections were predominantly Cross Traffic (DCA 110) crashes, Right Through (DCA 121) crashes and Lane Change and Side Swipe type (DCA 133-137) crashes
- The number of crashes at traffic signals and roundabouts configured at cross intersections were higher than the average proportions of crashes at all traffic signals and roundabouts
- Crashes occurring at T-intersections were predominantly at unsignalised locations

The characteristics for crashes at cross intersections and T-intersections are further explored in Appendix A Tables A55 and A56 and indicate similar crash characteristics.

4.2 Intersection Control

Table 2 (overleaf) shows the key crash characteristics for signalised intersections, roundabouts and unsignalised intersections ('No Control', Give Way sign and Stop sign controlled intersections) compared with the overall statistics.

Table 2: Summary of Crash Statistics by Intersection Control

Characteristic		Traffic Signals	Roundabouts	Unsignalised Intersections	All Intersections
Number of crashes in 5 year period		546 (26%)	179 (9%)	1371 (65%)	2104
Crash Severity	Fatality	1%	1%	4%	3%
	Serious Injury	47%	36%	49%	47%
	Other Injury	52%	63%	47%	50%
Weather	Wet	9%	7%	8%	8%
	Dry	89%	92%	91%	91%
Light	Day	66%	74%	70%	69%
	Dusk	10%	12%	11%	11%
	Dark	24%	14%	19%	20%
Behaviour	Vehicle Driver	73%	89%	76%	76%
	Motorcycle Rider	22%	8%	23%	22%
	Undetermined	4%	3%	1%	2%
Predominant Crash Types	Cross Traffic (DCA 110)	7%	**55%**	12%	14%
	Right Far (DCA 111)	1%	6%	5%	4%
	Right Near (DCA 113)	5%	10%	**24%**	18%
	Left Near (DCA 116)	1%	5%	3%	3%
	Right Through (DCA 121)	**48%**	6%	**24%**	29%
	Rear End (DCA 130 – 132)	16%	8%	10%	12%
	Lane Change & Side Swipe (DCA 133 – 137)	15%	7%	10%	11%
Intersection Geometry	Cross Intersections	71%	79%	31%	46%
	T-Intersections	23%	14%	67%	51%
	Y-Intersections	N/A	N/A	1%	N/A
	Multiple / Complex	6%	7%	1%	3%

Table 2 summarises the information discussed in Section 3 of this report and indicates distinct motorcycle crash patterns at each of the three intersection control types, including the following notes:

- Over 65% of motorcycle intersection crashes occurred at unsignalised intersections with a further 26% at traffic signals and 9% at roundabouts
- The crash severity at roundabouts was considerably lower than the other intersection control types
- Approximately three quarters of all crashes were attributed to driver behaviour. The Police reports indicated crashes at roundabouts were found to occur more frequently due to driver behavior, that is the driver did not give way to the motorcycle (89% of roundabout crashes) than the other intersection control types
- The predominant crash type at signalised intersections was the Right Through (DCA 121) crash representing 48% of motorcycle crashes at traffic signals
- The predominant crash type at roundabouts was the Cross Traffic (DCA 110) crash representing 55% of crashes at roundabouts
- The predominant crash types at unsignalised intersections were Right Near (DCA 113) and Right Through (DCA 121) crashes each representing 24% of crashes at unsignalised intersections
- Rear End type crashes (DCA 130 – 132) and Lane Change and Side Swipe type crashes (DCA 133 – 137) did not represent the predominant crash types at any of the intersection control types, however these crash types represented over 10% of motorcycle intersection crashes at all intersections except roundabouts
- A high proportion of signalised intersection crashes and roundabout crashes occurred at cross intersections (71% and 79% respectively)
- Two thirds of the crashes at unsignalised intersections occurred at T-intersections

4.2.1 Signalised Intersections

The findings for the key crash characteristics at signalised intersections (only) are summarised with respect to cross intersections, T-intersections and multiple / complex intersections and the complete data is presented in Appendix A Table A57. Crashes at Y-intersections are omitted from the table as no crashes were recorded at signalised Y-intersections during the 5 year crash period.

The analysis indicates the following key findings for motorcycle crashes specifically at signalised intersections:

- Over 70% of crashes at traffic signals occurred at cross intersections and 23% at T-intersections
- The crashes at signalised T-intersections included a slightly higher proportion of wet weather crashes compared with the overall average

- There were a higher proportion of crashes at night at signalised intersections (at each of the intersection geometry types) compared with all motorcycle intersection crashes
- Crashes at signalised T-intersections and multiple / complex intersections involved a higher proportion of motorcyclist error compared with the average statistics
- The predominant crash pattern at all signalised intersections was the Right Through (DCA 121) crash
- The crashes at signalised cross intersections and T-intersections also included a higher proportion of Rear End (DCA 130 – 132) and Lane Change and Side Swipe (DCA 133 – 137) type crashes compared with the overall average crash statistics
- The crashes at multiple / complex intersections included a higher proportion of Cross Traffic (DCA 110) crashes (which indicates one participant entered the intersection facing a red signal) compared with the average motorcycle intersection crashes
- The crashes at signalised intersections predominantly occurred in 60km/h speed zones which is likely to be a reflection of the spread of traffic signals throughout the road network rather than a motorcycle trend alone

4.2.2 Roundabouts

The findings for the key crash characteristics at roundabouts (only) are summarised in respect to cross intersections, T-intersections and multiple / complex intersections and presented in Appendix A Table A58. Crashes at Y-intersections are omitted from the table as no collisions have been recorded at Y-intersection roundabouts during the five year period.

The analysis indicates the following key findings for motorcycle crashes specifically at roundabouts:

- Nearly 80% of motorcycle crashes at roundabouts occurred at cross intersections with 14% at T-intersections and 7% at multiple / complex intersections
- The crashes at T-intersection roundabouts occurred more frequently during daylight conditions compared with the other intersection geometry types and the average at all motorcycle crashes indicating lack of lighting was not a key contributing factor
- Motorcycle crashes at cross intersection roundabouts were predominantly Cross Traffic (DCA 110) crashes which represented 65% of all roundabout crashes at cross intersections
- Crashes at T-intersection roundabouts included a wider spread of crash types with 33% Right Near (DCA 113) crashes, 17% Right Far (DCA 111) crashes and 13% Lane Change and Side Swipe type (DCA 133 – 137) crashes
- Crashes at multiple / complex roundabouts were predominantly Cross Traffic (DCA 110) crashes with 15% Right Far (DCA 111) crashes, 15% Left Near (DCA 116) crashes and 15% Lane Change and Side Swipe type (DCA 133 – 137) crashes

- The crashes at T-intersection roundabouts occurred in lower speed zones compared with both the average motorcycle crashes and other motorcycle crashes at roundabouts. This is likely to be due to the locations of T-intersection roundabouts within the road network rather than a motorcycle trend alone (i.e. located on local streets)

4.2.3 Unsignalised Intersections

The key crash characteristics for unsignalised intersections (i.e. with Give Way or Stop sign control, including the crashes coded 'No Control') configured at cross intersections, T-intersections and multiple / complex intersections compared with the overall average for all intersection control types are shown in Appendix A Table A59. Y-intersections are omitted from the table due to the low number of motorcycle crashes occurring at these locations (10 crashes in the 5 year period).

The analysis indicates the following key findings for motorcycle crashes at unsignalised intersections:

- Over two thirds of crashes at unsignalised intersections occurred at T-intersections (921 crashes) with 31% at cross intersections (420 crashes)
- Wet weather and dark conditions were found to not be contributing factors with the proportions occurring at each of the unsignalised intersection geometry types being less than the average for all motorcycle crashes
- The predominant crash types at unsignalised cross intersections were Cross Traffic (DCA 110) crashes and Right Through (DCA 121) crashes
- The predominant crash types at unsignalised T-intersections were Right Near (DCA 113) crashes and Right Through (DCA 121) crashes
- The crashes at unsignalised cross intersections and T-intersections predominantly occurred in 60km/h speed zones which is consistent with the findings for all motorcycle intersection crashes

5 CONCLUSION

The contributing factors to motorcycle crashes at intersections have been analysed with cross-correlation between factors and with particular reference to written Police reports to supplement the information provided by standard crash reports.

The analysis has identified the most common types of crashes involving motorcyclists at intersections were:

- Right Through (DCA 121) crashes (603 crashes representing 29%)
- Right Near (DCA 113) crashes (373 crashes representing 18%)
- Cross Traffic (DCA 110) crashes (304 crashes representing 14%)

Over two thirds of the motorcycle and motor scooter crashes occurred on the arterial road network with the majority of crashes occurring specifically on primary arterial roads. More than half of the motorcycle collisions occurred in 60km/h speed zones, with a further 17% in 50km/h speed zones and 12% in 80km/h speed zones. As would be expected, the severity of the crashes generally increased on roads with higher speed limits.

Over 80% of motorcycle and motor scooter intersection crashes occurred in the Melbourne metropolitan area (defined by the VicRoads metropolitan regions). The intersection crashes in regional areas were found to result in higher severity crashes which were generally due to higher speeds.

Over three quarters (78%) of crashes occurred at intersections along a public transport route however the public transport vehicles and infrastructure (e.g. tram tracks) were found to not be a significant contributing factor to motorcycle collisions with only 1% of crashes directly involving a public transport vehicle or infrastructure.

It is noted that wet weather was found to not contribute significantly to crashes. It is acknowledged that a wet road surface provides less traction for all road users and visibility is generally poor during wet weather. The general trend of motorcycle crashes suggests that motorcyclists choose not to ride during wet conditions when possible.

The analysis identified the common crash scenario involved the driver of another vehicle failing to recognize and give way to an approaching motorcyclist. A basic interpretation of the Police reports indicated approximately 76% of motorcycle crashes resulted from driver error, 21% resulted from motorcycle rider error and 2% were either undetermined or involved both participants making an error simultaneously.

Although anecdotally motorcycle speed is considered to be a significant factor in motorcycle collisions, less than 1% of the Police reports included an indication of the motorcyclist travelling at high speed.

A small proportion of the motorcycle intersection crashes included motorcyclists 'lane splitting' at the time of the collision (4% of the total number of crashes). During Right Through (DCA 121) crashes at unsignalised intersections, however, motorcyclists were found to be travelling straight through the intersection and 'lane splitting' between queued vehicles during 11% of crashes (36 collisions).

Similarly, motorcyclists legally travelling in the kerbside lane adjacent to queued vehicles were found overall to not be a significant factor in motorcycle intersection collisions (3% of the total number of crashes). During Right Through (DCA 121) crashes at unsignalised intersections, however, motorcyclists were found to be travelling straight through the intersection in the kerbside lane adjacent to queued vehicles during 9% of crashes (30 collisions).

The Police reports included few descriptions of drivers 'not seeing' motorcyclists (1% of crashes). The reasons for this included the visibility to the motorcyclist being obscured by vehicles in adjacent lanes (generally 4WD's and trucks), vehicles turning ahead of the motorcyclist or the horizontal alignment of the road restricting sight distance.

The high proportion of Cross Traffic and Right Near crashes at unsignalised intersections which could generally be attributed to vehicles pulling away from the holding line into the path of an approaching motorcyclist indicates drivers may have difficulty identifying motorcyclists' presence (due to the size of the motorcycle compared with surrounding traffic) or assessing motorcycle speed when assessing gaps in traffic approaching from two directions.

Just over half of the motorcycle intersection collisions occurred at T-intersections, and more than 45% at cross intersections. The analysis indicated similar crash patterns at the two types of intersection geometry with similar proportions of Right Through (DCA Code 121) crashes and rear end type (DCA 130-132) crashes across all intersection control types.

A high proportion of Cross Traffic crashes occurred at cross intersections (30% or 287 crashes), and by definition, these were not reported at T-intersections. A similar number of Right Near (DCA 113) crashes occurred at T-intersections (291 crashes), however, which require a similar assessment from drivers to assess gaps in approaching traffic from two directions.

The majority of motorcycle crashes were found to occur at unsignalised intersections with Give Way sign or Stop sign control on the minor approach. Reference has not been made to the number of unsignalised intersections within the road network compared with traffic signals and roundabouts, or the exposure (volume of general traffic and motorcycles), and it is therefore difficult to assess the relative safety of the intersection control alone.

The crashes at unsignalised intersections (with 'No Control', Give Way sign and Stop sign control) included a variety of crash types and generally occurred in 60km/h speed zones. The following crash types were predominant at unsignalised cross and T-intersections:

- Right Through (DCA Code 121) crashes
- Right Near (DCA Code 113) crashes
- Cross Traffic (DCA Code 110) crashes

Motorcycle collisions at signalised intersections represented just over a quarter of the total number of crashes.

The most common crash type at traffic signals was the Right Through (DCA Code 121) crash involving the vehicle driver turning right and the motorcyclist travelling straight through the intersection.

Almost a third of crashes at traffic signals were rear end type (DCA 130-132) crashes which comprised an almost even mix of vehicles striking motorcyclists, and motorcyclists striking vehicles. The severity of these crashes was lower than other crash types and occurred more often in wet weather at cross intersections.

It is interesting to note that 15% of motorcycle crashes at traffic signals involved the participants entering the intersection from adjacent directions, indicating one participant entered the intersection facing a red signal display. The information provided in the Police reports did not indicate a clear pattern of which participant entered the intersection illegally or the reasons for entering the intersection facing the red display.

Only 9% of motorcycle crashes occurred at roundabouts and these were generally found to be of lower severity with the participants entering the intersection from adjacent directions. The Police reports indicate the common crashes at roundabouts involved drivers entering the intersection into the path of an approaching motorcyclist. The Police reports indicated that motorcyclist speed was a factor in less than 1% of these collisions.

With consideration to the analysis and findings within this report, the common crash scenarios involving motorcyclists at intersections are shown in Table 3.

Table 3: Predominant crash scenarios involving motorcyclists at intersections

Intersection Control		Crash Type	Number of Crashes
Traffic signals		Right Through (DCA 121)	261 crashes
Roundabouts		Cross traffic type crashes (DCA 110 – 116)	135 crashes
Unsignalised Intersections	Cross Intersections	Cross Traffic (DCA 110)	165 crashes
		Right Through (DCA 121)	84 crashes
	T-Intersections	Right Near (DCA 113)	268 crashes
		Right Through (DCA 121)	246 crashes

The crashes in Table 3 generally occurred in 60km/h speed zones on primary arterial roads in dry, daylight conditions. Up to 20% of the Right Through crashes at unsignalised intersections included motorcyclists 'lane splitting' or travelling legally in the kerbside lane adjacent to queued vehicles at the time of the crash.

Part 2 of the Study will investigate infrastructural and technological solutions to address the crash types for the intersection controls identified in Table 3.

A further useful investigation would include an assessment of the intersections throughout Victoria with consideration to the level of exposure in order to determine if one form of intersection control or geometry is safer for motorcyclists than other forms.

APPENDIX A: Crash Data

Table A1: Number of casualty crashes by severity by year

Year	Fatal	Serious Injury	Other Injury	Total	
				Number	%
2003	12	162	203	377	17.9%
2004	11	189	232	432	20.5%
2005	14	189	259	462	22.0%
2006	13	212	179	404	19.2%
2007	12	240	177	429	20.4%
Total	62	992	1050	2104	100%

Table A2: Number of casualty crashes by severity by month of year

Month	Fatal	Serious Injury	Other Injury	Total	
				Number	%
January	2	68	93	163	7.7%
February	6	74	105	185	8.8%
March	4	100	107	211	10.0%
April	7	79	86	172	8.2%
May	4	89	101	194	9.2%
June	3	73	68	144	6.8%
July	4	58	90	152	7.2%
August	4	79	70	153	7.3%
September	4	79	78	161	7.7%
October	10	97	89	196	9.3%
November	8	97	79	184	8.7%
December	6	99	84	189	9.0%
Total	62	992	1050	2104	100.0%

Table A3: Number of casualty crashes by weather conditions

Behaviour	Fatal	Serious Injury	Other Injury	Total	
				Number	%
Dry	58	905	945	1908	90.7%
Wet	4	81	89	174	8.3%
Unknown	0	6	16	22	1.0%
Total	**62**	**992**	**1050**	**2104**	**100.0%**

Table A4: Number of casualty crashes by light conditions

Behaviour	Fatal	Serious Injury	Other Injury	Total	
				Number	%
Day	46	675	735	1456	69.2%
Dark	12	213	193	418	19.9%
Dawn	0	0	0	0	0.0%
Dusk	4	104	122	230	10.9%
Total	**62**	**992**	**1050**	**2104**	**100.0%**

Table A5: Number of casualty crashes by severity by road classification

Road Classification	Fatal	Serious Injury	Other Injury	Total	
				Number	%
Freeway	0	11	18	29	**1.4%**
Primary Arterial	45	585	580	1210	**57.5%**
Secondary Arterial	3	86	108	197	**9.4%**
Major Road	3	159	171	333	**15.8%**
Collector Road	5	37	64	106	**5.0%**
Local Road	6	114	109	229	**10.9%**
Total	**62**	**992**	**1050**	**2104**	**100%**

Table A6: Number of casualty crashes in metropolitan Melbourne and regional Victoria

Location	Fatal	Serious Injury	Other Injury	Total	
				Number	%
Metropolitan Melbourne	42 (2%)	810 (46%)	903 (51%)	1755	**83.4%**
Regional Victoria	20 (6%)	182 (52%)	147 (42%)	349	**16.6%**
Total	**62**	**992**	**1050**	**2104**	**100.0%**

Table A7: Number of casualty crashes by public transport route

Public Transport Route	Fatal	Serious Injury	Other Injury	Total	
				Number	%
Level Crossing	0	0	2	2	**0.1%**
Bus	33	488	521	1042	**49.5%**
Tram	1	69	113	183	**8.7%**
Level Crossing & Bus	1	9	10	20	**1.0%**
Tram & Bus	0	89	99	188	**8.9%**
Level Crossing & Tram	0	0	0	0	**0.0%**
No Public Transport Route	27	337	305	669	**31.8%**
Total	**62**	**992**	**1050**	**2104**	**100.0%**

Table A8: Number of casualty crashes by severity by DCA group

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	23	404	426	853	40.5%
120 – 129 Vehicles from opposing directions	26	327	267	620	29.5%
130 Vehicles from the same direction	6	182	293	481	22.9%
140 Manoeuvring	4	34	44	82	3.9%
150 Overtaking	3	45	19	67	3.2%
199 Unknown	0	0	1	1	0.0%
Total	**62**	**992**	**1050**	**2104**	**100%**

Table A9: Number of casualty crashes by severity for vehicles from adjacent directions – DCA Codes 110–119

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 Cross Traffic	5	151	148	**304**	**35.6%**
111 Right Far	1	34	46	**81**	**9.5%**
112 Left Far	0	0	2	**2**	**0.2%**
113 Right Near	14	184	175	**373**	**43.7%**
114 Two Right Turning	0	1	7	**8**	**0.9%**
115 Right / Left Far	0	5	3	**8**	**0.9%**
116 Left Near	2	21	39	**62**	**7.3%**
117 Right / Left Near	0	0	0	**0**	**0.0%**
118 Two Left Turn	0	0	1	**1**	**0.1%**
119 Other Adjacent	1	8	5	**14**	**1.6%**
Total	**23**	**404**	**426**	**853**	**100.0%**

Table A10: Number of casualty crashes by severity for vehicles from opposing directions – DCA Codes 120–129

DCA Group	Fatal	Serious	Other	Total	
				Number	%
120 Head On	1	2	1	**4**	**0.6%**
121 Right Through	25	319	259	**603**	**97.3%**
122 Left Through	0	1	0	**1**	**0.2%**
123 Right / Left	0	4	7	**11**	**1.8%**
124 Right / Right	0	0	0	**0**	**0.0%**
125 Left / Left	0	0	0	**0**	**0.0%**
126 -	0	0	0	**0**	**0.0%**
127 -	0	0	0	**0**	**0.0%**
128 -	0	0	0	**0**	**0.0%**
129 Other Opposing	0	1	0	**1**	**0.2%**
Total	**26**	**327**	**267**	**620**	**100.0%**

Table A11: Number of casualty crashes by severity for vehicles from the same direction – DCA Codes 130–139

DCA Group	Fatal	Serious	Other	Total	
				Number	%
130 Rear End	0	53	84	**137**	**28.5%**
131 Left Rear	0	5	28	**33**	**6.9%**
132 Right Rear	5	36	31	**72**	**15.0%**
133 Lane Side Swipe	0	6	16	**22**	**4.6%**
134 Lane Change Right	0	13	7	**20**	**4.2%**
135 Lane Change Left	0	14	32	**46**	**9.6%**
136 Right Turn Side Swipe	0	27	49	**76**	**15.8%**
137 Left Turn Side Swipe	1	26	39	**66**	**13.7%**
138 -	0	0	0	**0**	**0.0%**
139 Other Same Direction	0	2	7	**9**	**1.9%**
Total	**6**	**182**	**293**	**481**	**100.0%**

Table A12: Number of casualty crashes by severity for vehicles manoeuvring – DCA Codes 140–149

DCA Group	Fatal	Serious	Other	Total	
				Number	%
140 U-Turn	4	23	27	**54**	**65.9%**
141 U-turn into Stationary Object or Vehicle	0	0	0	**0**	**0.0%**
142 Leaving Parking	0	0	0	**0**	**0.0%**
143 Entering Parking	0	0	0	**0**	**0.0%**
144 Parking Vehicles	0	0	0	**0**	**0.0%**
145 Reversing	0	1	2	**3**	**3.7%**
146 Reversing into Stationary Object or Vehicle	0	0	0	**0**	**0.0%**
147 Emerging from Driveway or Laneway	0	8	8	**16**	**19.5%**
148 Emerging from Footway	0	1	5	**6**	**7.3%**
149 Other Manoeuvring	0	1	2	**3**	**3.7%**
Total	**4**	**34**	**44**	**82**	**100.0%**

Table A13: Number of casualty crashes by severity for vehicles overtaking – DCA Codes 150–159

DCA Group	Fatal	Serious	Other	Total	
				Number	%
150 Head On	0	1	0	**1**	**1.5%**
151 Out of Control	0	0	0	**0**	**0.0%**
152 Pulling Out	3	43	18	**64**	**95.5%**
153 Cutting In	0	0	0	**0**	**0.0%**
154 Pulling Out – Rear End	0	1	0	**1**	**1.5%**
155 -	0	0	0	**0**	**0.0%**
156 -	0	0	0	**0**	**0.0%**
157 -	0	0	0	**0**	**0.0%**
158 -	0	0	0	**0**	**0.0%**
159 Other Overtaking	0	0	1	**1**	**1.5%**
Total	**3**	**45**	**19**	**67**	**100.0%**

Table A14: Number of casualty crashes by severity and behaviour

Participant	Fatal	Serious	Other	Total	
				Number	%
Motorcycle Rider	18	223	210	**451**	**21.4%**
Other Driver	43	744	818	**1605**	**76.3%**
Undetermined	1	25	22	**48**	**2.3%**
Total	**62**	**992**	**1050**	**2104**	**100.0%**

Table A15: Number of casualty crashes by severity and speed zone

Speed Zone	Fatal	Serious	Other	Total	
				Number	%
40km/h	1	10	19	**30**	**1.4%**
50km/h	4	157	193	**354**	**16.8%**
60km/h	18	539	607	**1164**	**55.3%**
70km/h	8	103	83	**194**	**9.2%**
80km/h	13	125	112	**250**	**11.9%**
90km/h	3	6	4	**13**	**0.6%**
100km/h	15	51	32	**98**	**4.7%**
110km/h	0	1	0	**1**	**0.0%**
Total	**62**	**992**	**1050**	**2104**	**100.0%**

Table A16: Number of casualty crashes by severity in a 40km/h speed zone

Speed Zone	Fatal	Serious	Other	Total	
				Number	%
40km/h	1	10	19	**30**	**100.0%**

Table A17: Number of casualty crashes by severity in a 40km/h speed zone

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	0	3	6	**9**	**30.0%**
120 – 129 Vehicles from opposing directions	1	5	6	**12**	**40.0%**
130 Vehicles from the same direction	0	2	4	**6**	**20.0%**
140 Manoeuvring	0	0	2	**2**	**6.7%**
150 Overtaking	0	0	1	**1**	**3.3%**
199 Unknown	0	0	0	**0**	**0.0%**
Total	**1**	**10**	**19**	**30**	**100.0%**

Table A18: Number of casualty crashes by severity in a 50km/h speed zone

Speed Zone	Fatal	Serious	Other	Total	
				Number	%
50km/h	4	157	193	**354**	**100.0%**

Table A19: Number of casualty crashes by severity in a 50km/h speed zone

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	0	66	96	**162**	**45.8%**
120 – 129 Vehicles from opposing directions	4	50	39	**93**	**26.3%**
130 Vehicles from the same direction	0	24	39	**63**	**17.8%**
140 Manoeuvring	0	3	16	**19**	**5.4%**
150 Overtaking	0	14	3	**17**	**4.8%**
199 Unknown	0	0	0	**0**	**0.0%**
Total	**4**	**157**	**193**	**354**	**100.0%**

Table A20: Number of casualty crashes by severity in a 60km/h speed zone

Speed Zone	Fatal	Serious	Other	Total	
				Number	%
60km/h	18	539	607	**1164**	**100.0%**

Table A21: Number of casualty crashes by severity in a 60km/h speed zone

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	8	215	225	**448**	**38.5%**
120 – 129 Vehicles from opposing directions	6	202	178	**386**	**33.2%**
130 Vehicles from the same direction	2	91	177	**270**	**23.2%**
140 Manoeuvring	0	14	16	**30**	**2.6%**
150 Overtaking	2	17	11	**30**	**2.6%**
199 Unknown	0	0	0	**0**	**0.0%**
Total	**18**	**539**	**607**	**1164**	**100.0%**

Table A22: Number of casualty crashes by severity in a 70km/h speed zone

Speed Zone	Fatal	Serious	Other	Total	
				Number	%
70km/h	8	103	83	**194**	**100.0%**

Table A23: Number of casualty crashes by severity in a 70km/h speed zone

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	4	39	31	74	**38.1%**
120 – 129 Vehicles from opposing directions	3	30	23	56	**28.9%**
130 Vehicles from the same direction	0	26	25	51	**26.3%**
140 Manoeuvring	1	4	3	8	**4.1%**
150 Overtaking	0	4	1	5	**2.6%**
199 Unknown	0	0	0	0	**0.0%**
Total	**8**	**103**	**83**	**194**	**100.0%**

Table A24: Number of casualty crashes by severity in a 80km/h speed zone

Speed Zone	Fatal	Serious	Other	Total	
				Number	%
80km/h	13	125	112	**250**	**100.0%**

Table A25: Number of casualty crashes by severity in a 80km/h speed zone

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	4	54	50	**108**	**43.2%**
120 – 129 Vehicles from opposing directions	6	30	16	**52**	**20.8%**
130 Vehicles from the same direction	1	25	39	**65**	**26.0%**
140 Manoeuvring	2	12	7	**21**	**8.4%**
150 Overtaking	0	4	0	**4**	**1.6%**
199 Unknown	0	0	0	**0**	**0.0%**
Total	**13**	**125**	**112**	**250**	**100.0%**

Table A26: Number of casualty crashes by severity in a 90km/h speed zone

Speed Zone	Fatal	Serious	Other	Total	
				Number	%
90km/h	3	6	4	**13**	**100.0%**

Table A27: Number of casualty crashes by severity in a 90km/h speed zone

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	1	1	4	**6**	**46.2%**
120 – 129 Vehicles from opposing directions	0	2	0	**2**	**15.4%**
130 Vehicles from the same direction	0	2	0	**2**	**15.4%**
140 Manoeuvring	1	0	0	**1**	**7.7%**
150 Overtaking	1	1	0	**2**	**15.4%**
199 Unknown	0	0	0	**0**	**0.0%**
Total	**3**	**6**	**4**	**13**	**100.0%**

Table A28: Number of casualty crashes by severity in a 100km/h speed zone

Speed Zone	Fatal	Serious	Other	Total	
				Number	%
100km/h	15	51	31	**97**	**100.0%**

Table A29: Number of casualty crashes by severity in a 100km/h speed zone

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	6	25	14	**45**	**46.4%**
120 – 129 Vehicles from opposing directions	6	8	5	**19**	**19.6%**
130 Vehicles from the same direction	3	12	9	**24**	**24.7%**
140 Manoeuvring	0	1	0	**1**	**1.0%**
150 Overtaking	0	5	3	**8**	**8.2%**
199 Unknown	0	0	0	**0**	**0.0%**
Total	**15**	**51**	**31**	**97**	**100.0%**

Table A30: Number of casualty crashes by severity by intersection geometry

Intersection Geometry	Fatal	Serious	Other	Total	
				Number	%
Cross Intersection	15	454	490	**959**	**45.6%**
T-Intersection	46	501	524	**1071**	**50.9%**
Y-Intersection	0	6	4	**10**	**0.5%**
Multiple / Complex Intersection	1	31	32	**64**	**3.0%**
Total	**62**	**992**	**1050**	**2104**	**100.0%**

Table A31: Number of casualty crashes by severity and DCA Code at cross intersections and T-intersections

DCA Code	Fatal	Serious	Other	Total	
				Number	%
Cross Intersection					
DCA 110 Cross Traffic	5	141	141	**287**	-
DCA 113 Right Near	1	37	34	**72**	-
DCA 121 Right Through	6	154	133	**293**	-
DCA 130-132 Rear End Type Crashes	2	35	73	**110**	-
DCA 152 Pulling Out	0	7	2	**9**	-
Total	**14**	**374**	**383**	**771**	-
T-Intersection					
DCA 110 Cross Traffic	0	1	0	**1**	-
DCA 113 Right Near	12	142	137	**291**	-
DCA 121 Right Through	19	157	121	**297**	-
DCA 130-132 Rear End Type Crashes	3	57	66	**126**	-
DCA 152 Pulling Out	3	35	16	**54**	-
Total	**37**	**392**	**340**	**769**	-

Table A32: Number of casualty crashes by severity at multiple / complex intersections

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	1	16	13	**30**	**46.9%**
120 – 129 Vehicles from opposing directions	0	9	5	**14**	**21.9%**
130 Vehicles from the same direction	0	5	13	**18**	**28.1%**
140 Manoeuvring	0	0	1	**1**	**1.6%**
150 Overtaking	0	1	0	**1**	**1.6%**
199 Unknown	0	0	0	**0**	**0.0%**
Total	**1**	**31**	**32**	**64**	**100.0%**

Table A33: Number of casualty crashes by severity by intersection control

Intersection Control	Fatal	Serious Injury	Other Injury	Total	
				Number	%
Stop sign	1	52	63	116	**5.5%**
Give Way sign	11	155	175	341	**16.2%**
Roundabout	2	64	113	179	**8.5%**
Traffic signals	7	255	284	546	**26.0%**
Rail Level Crossing	0	0	1	1	**0.0%**
No control	41	465	408	914	**43.4%**
Police Detour	0	0	2	2	**0.1%**
Traffic Signals out of order	0	1	4	5	**0.2%**
Total	**62**	**992**	**1050**	**2104**	**100.0%**

Table A34: Number of casualty crashes by severity and DCA code at signalised intersections

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	2	40	41	**83**	**15.2%**
120 – 129 Vehicles from opposing directions	5	145	120	**270**	**49.5%**
130 Vehicles from the same direction	0	63	110	**173**	**31.7%**
140 Manoeuvring	0	4	13	**17**	**3.1%**
150 Overtaking	0	3	0	**3**	**0.5%**
199 Unknown	0	0	0	**0**	**0.0%**
Total	**7**	**255**	**284**	**546**	**100.0%**

Table A35: Number of crashes with the participant entering the intersection facing a red signal lantern (confirmed in the Police report)

Participant	Fatal	Serious	Other	Total	
				Number	%
Other Driver	1	17	19	**37**	**66.1%**
Motorcyclist	0	11	8	**19**	**33.9%**
Total	**1**	**28**	**27**	**56**	-

Table A36: Number of crashes with the participant turning right during Right Through (DCA 121) crashes at signalised intersections

Participant	Fatal	Serious	Other	Total	
				Number	%
Other Driver	1	106	92	**199**	**76.2%**
Motorcyclist	4	34	24	**62**	**23.8%**
Total	**5**	**140**	**116**	**261**	**100.0%**

Table A37: Road surface conditions during rear end type crashes at signalised intersections

Road Surface Condition	Fatal	Serious	Other	Total	
				Number	%
Wet Surface	0	15	7	**22**	**8.4%**
Dry Surface	5	124	107	**236**	**90.4%**
Unknown	0	1	2	**3**	**1.1%**
Total	**5**	**140**	**116**	**261**	**100.0%**

Table A38: Number of casualty crashes by severity and DCA code at roundabouts

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	1	54	83	**138**	**77.1%**
120 – 129 Vehicles from opposing directions	0	4	6	**10**	**5.6%**
130 Vehicles from the same direction	1	5	23	**29**	**16.2%**
140 Manoeuvring	0	1	1	**2**	**1.1%**
150 Overtaking	0	0	0	**0**	**0.0%**
199 Unknown	0	0	0	**0**	**0.0%**
Total	**2**	**64**	**113**	**179**	**100.0%**

Table A39: Number of crashes with the participant failing to give way during cross traffic type crashes at roundabouts

Participant	Fatal	Serious	Other	Total	
				Number	%
Other Driver	1	55	82	**138**	**95.2%**
Motorcyclist	0	2	5	**7**	**4.8%**
Total	**1**	**57**	**87**	**145**	**100.0%**

Table A40: Number of crashes with the participant failing to stop on the approaches to roundabouts

Participant	Fatal	Serious	Other	Total	
				Number	%
Other Driver	0	1	7	**8**	**61.5%**
Motorcyclist	0	1	4	**5**	**38.5%**
Total	**0**	**2**	**11**	**13**	**100.0%**

Table A41: Number of casualty crashes by severity and DCA code at 'No Control' intersections

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	20	309	301	**630**	**46.0%**
120 – 129 Vehicles from opposing directions	21	178	140	**339**	**24.7%**
130 Vehicles from the same direction	5	114	155	**274**	**20.0%**
140 Manoeuvring	4	29	30	**63**	**4.6%**
150 Overtaking	3	42	19	**64**	**4.7%**
199 Unknown	0	0	0	**0**	**0.0%**
Total	**53**	**672**	**645**	**1370**	**100.0%**

Table A42: Number of crashes with the participant failing to give way during Right Through (DCA 121) crashes at 'No Control' intersections

Participant	Fatal	Serious	Other	Total	
				Number	%
Other Driver	20	170	125	**315**	**95.2%**
Motorcyclist	0	5	9	**14**	**4.2%**
Undetermined	0	0	2	**2**	**0.6%**
Total	**20**	**175**	**136**	**331**	**100.0%**

Table A43: Number of crashes with the participant failing to give way during Right Near (DCA 113) crashes at 'No Control' intersections

Participant	Fatal	Serious	Other	Total	
				Number	%
Other Driver	7	152	138	**297**	**90.3%**
Motorcyclist	5	17	7	**29**	**8.8%**
Undetermined	0	2	1	**3**	**0.9%**
Total	**12**	**171**	**146**	**329**	**100.0%**

Table A44: Number of crashes with the participant failing to give way during Cross Traffic (DCA 110) crashes at 'No Control' intersections

Participant	Fatal	Serious	Other	Total	
				Number	%
Other Driver	5	75	57	**137**	**81.1%**
Motorcyclist	0	12	19	**31**	**18.3%**
Undetermined	0	1	0	**1**	**0.6%**
Total	**5**	**88**	**76**	**169**	**100.0%**

Table A45: Number of crashes with the participant failing to give way during Right Far (DCA 111) crashes at 'No Control' intersections

Participant	Fatal	Serious	Other	Total	
				Number	%
Other Driver	1	14	25	**40**	**64.5%**
Motorcyclist	0	13	9	**22**	**35.5%**
Total	**1**	**27**	**34**	**62**	**100.0%**

Table A46: Number of crashes with the participant failing to stop during rear end type (DCA 130 – 132) crashes at 'No Control' intersections

Participant	Fatal	Serious	Other	Total	
				Number	%
Other Driver	2	13	32	**47**	**34.3%**
Motorcyclist	3	47	39	**89**	**65.0%**
Undetermined	0	0	1	**1**	**0.7%**
Total	**5**	**60**	**72**	**137**	**100.0%**

Table A47: Common crash scenarios in lane change and side swipe type crashes at 'No Control' intersections

Scenario	Fatal	Serious	Other	Total	
				Number	%
Motorcyclist overtaking turning vehicle	0	13	18	**31**	**23.3%**
Driver changing lanes	0	22	35	**57**	**42.9%**
Both vehicles turning - driver turned into motorcyclist	0	2	8	**10**	**7.5%**
Other factors	0	16	19	**35**	**26.3%**

Table A48: Number of casualty crashes by severity and DCA code at Give Way sign controlled intersections

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	7	132	136	**275**	**80.9%**
120 – 129 Vehicles from opposing directions	3	11	7	**21**	**6.2%**
130 Vehicles from the same direction	0	5	24	**29**	**8.5%**
140 Manoeuvring	1	6	6	**13**	**3.8%**
150 Overtaking	0	1	1	**2**	**0.6%**
199 Unknown	0	0	0	**0**	**0.0%**
Total	**11**	**155**	**174**	**340**	**100.0%**

Table A49: Light conditions during Left Near (DCA 116) crashes at Give Way sign controlled intersections

Participant	Fatal	Serious	Other	Total	
				Number	%
Day	0	2	4	**6**	**33.3%**
Dark	0	3	7	**10**	**55.6%**
Dusk	0	0	2	**2**	**11.1%**
Total	**0**	**5**	**13**	**18**	**100.0%**

Table A50: Number of casualty crashes by severity and DCA code at Stop sign controlled intersections

DCA Group	Fatal	Serious	Other	Total	
				Number	%
110 – 119 Vehicles from adjacent directions	1	29	42	**72**	**87.8%**
120 – 129 Vehicles from opposing directions	0	1	2	**3**	**3.7%**
130 Vehicles from the same direction	0	0	6	**6**	**7.3%**
140 Manoeuvring	0	0	1	**1**	**1.2%**
150 Overtaking	0	0	0	**0**	**0.0%**
199 Unknown	0	0	0	**0**	**0.0%**
Total	**1**	**30**	**51**	**82**	**100.0%**

Table A51: Number of crashes with the participant failing to give way
during Right Near (DCA 113) crashes at Stop sign controlled intersections

Participant	Fatal	Serious	Other	Total	
				Number	%
Other Driver	1	22	22	**45**	**88.2%**
Motorcyclist	0	2	4	**6**	**11.8%**
Total	**1**	**24**	**26**	**51**	**100.0%**

Table A52: Number of crashes with the participant failing to give way during Cross Traffic (DCA 110) crashes at Stop sign controlled intersections

Participant	Fatal	Serious	Other	Total	
				Number	%
Other Driver	0	21	9	**30**	**88.2%**
Motorcyclist	0	1	3	**4**	**11.8%**
Total	**0**	**22**	**12**	**34**	**100.0%**

Table A53: Light conditions during Left Near (DCA 116) crashes at Stop sign controlled intersections

Light Conditions	Fatal	Serious	Other	Total	
				Number	%
Day	0	2	4	6	54.5%
Dark	0	0	3	3	27.3%
Dusk	0	0	2	2	18.2%
Total	0	2	9	11	100.0%

Table A54: Number of crashes with the participant failing to give way during Right Far (DCA 111) crashes at Stop sign controlled intersections

Participant	Fatal	Serious	Other	Total	
				Number	%
Other Driver	0	1	4	5	83.3%
Motorcyclist	0	0	1	1	16.7%
Total	0	1	5	6	100.0%

Table A55: Summary of Crash Statistics by Intersection Control for Cross Intersections (Only)

Characteristic		Traffic Signals	Roundabouts	Unsignalised Intersections	All Intersections
Number of crashes in 5 year period		391 (41%)	142 (15%)	420 (44%)	2104
Crash Severity	Fatality	1%	1%	3%	3%
	Serious Injury	48%	37%	51%	47%
	Other Injury	52%	62%	46%	50%
Weather	Wet	9%	7%	7%	8%
	Dry	89%	92%	92%	91%
Light	Day	66%	72%	69%	69%
	Dusk	11%	13%	13%	11%
	Dark	23%	15%	18%	20%
Behaviour	Vehicle Driver	75%	89%	79%	76%
	Motorcycle Rider	21%	9%	20%	22%
	Undetermined	4%	2%	1%	2%
Predominant Crash Types	Cross Traffic (DCA 110)	7%	**65%**	**39%**	14%
	Right Far (DCA 111)	2%	3%	5%	4%
	Right Near (DCA 113)	2%	6%	13%	18%
	Left Near (DCA 116)	1%	4%	2%	3%
	Right Through (DCA 121)	**51%**	6%	**20%**	**29%**
	Rear End (DCA 130 – 132)	15%	8%	9%	12%
	Lane Change & Side Swipe (DCA 133 – 137)	15%	6%	7%	11%
Predominant Speed Zone	50km/h	19%	19%	21%	17%
	60km/h	**59%**	**50%**	**54%**	**55%**
	70km/h	10%	10%	5%	9%
	80km/h	12%	15%	7%	12%
	100km/h	0%	5%	9%	5%

Table A56: Summary of Crash Statistics by Intersection Control for T-Intersections (Only)

Characteristic		Traffic Signals	Roundabouts	Unsignalised Intersections	All Intersections
Number of crashes in 5 year period		124 (12%)	24 (2%)	921 (86%)	2104
Crash Severity	Fatality	3%	4%	4%	3%
	Serious Injury	44%	25%	48%	47%
	Other Injury	53%	**71%**	48%	50%
Weather	Wet	**11%**	8%	8%	8%
	Dry	87%	92%	91%	91%
Light	Day	65%	**88%**	71%	69%
	Dusk	10%	4%	10%	11%
	Dark	**25%**	8%	19%	20%
Behaviour	Vehicle Driver	68%	79%	75%	76%
	Motorcycle Rider	25%	13%	24%	22%
	Undetermined	7%	8%	1%	2%
Predominant Crash Types	Cross Traffic (DCA 110)	0%	4%	0%	14%
	Right Far (DCA 111)	2%	17%	4%	4%
	Right Near (DCA 113)	12%	**33%**	**29%**	**18%**
	Left Near (DCA 116)	2%	4%	4%	3%
	Right Through (DCA 121)	**40%**	4%	**27%**	**29%**
	Rear End (DCA 130 – 132)	19%	8%	11%	12%
	Lane Change & Side Swipe (DCA 133 – 137)	16%	13%	10%	11%
Predominant Speed Zone	50km/h	9%	**38%**	15%	17%
	60km/h	**62%**	**50%**	**55%**	**55%**
	70km/h	11%	4%	11%	9%
	80km/h	18%	4%	12%	12%
	100km/h	0%	0%	5%	5%

Table A57: Summary of Crash Statistics at Signalised Intersections by Intersection Geometry

Characteristic		Signalised Intersections: Cross Intersections	Signalised Intersections: T-Intersections	Signalised Intersections: Multiple / Complex Intersections	All Intersections
Number of crashes in 5 year period		391 (71%)	124 (23%)	31 (6%)	2104
Crash Severity	Fatality	1%	3%	N/A	3%
	Serious Injury	48%	44%	48%	47%
	Other Injury	52%	53%	52%	50%
Weather	Wet	9%	11%	6%	8%
	Dry	90%	87%	94%	91%
Light	Day	66%	65%	58%	69%
	Dusk	11%	10%	10%	11%
	Dark	23%	25%	**32%**	20%
Behaviour	Vehicle Driver	75%	68%	71%	76%
	Motorcycle Rider	21%	25%	29%	22%
	Undetermined	4%	7%	N/A	2%
Predominant Crash Types	Cross Traffic (DCA 110)	7%	N/A	**26%**	14%
	Right Near (DCA 113)	2%	12%	6%	18%
	Right Through (DCA 121)	**51%**	**40%**	**35%**	**29%**
	Rear End (DCA 130 – 132)	15%	19%	10%	12%
	Lane Change & Side Swipe (DCA 133 – 137)	15%	16%	**13%**	11%
	Pulling Out (DCA 152)	1%	N/A	N/A	3%
Speed Zone	50km/h	19%	9%	7%	17%
	60km/h	**59%**	**62%**	**71%**	**55%**
	70km/h	10%	11%	3%	9%
	80km/h	12%	18%	19%	12%

Table A58: Summary of Crash Statistics at Roundabouts by Intersection Geometry

Characteristic		Roundabouts: Cross Intersections	Roundabouts: T-Intersections	Roundabouts: Multiple / Complex Intersections	All Intersections
Number of crashes in 5 year period		142 (79%)	24 (13%)	13 (7%)	2104
Crash Severity	Fatality	1%	4%	N/A	3%
	Serious Injury	37%	25%	38%	47%
	Other Injury	**62%**	**71%**	**62%**	50%
Weather	Wet	7%	8%	8%	8%
	Dry	92%	92%	92%	91%
Light	Day	72%	**88%**	62%	69%
	Dusk	13%	4%	**15%**	11%
	Dark	15%	8%	**23%**	20%
Behaviour	Vehicle Driver	89%	79%	100%	76%
	Motorcycle Rider	9%	13%	N/A	22%
	Undetermined	2%	8%	N/A	2%
Predominant Crash Types	Cross Traffic (DCA 110)	**65%**	4%	**31%**	14%
	Right Far (DCA 111)	3%	**17%**	**15%**	4%
	Right Near (DCA 113)	6%	**33%**	8%	18%
	Left Near (DCA 116)	4%	4%	**15%**	3%
	Right Through (DCA 121)	6%	4%	8%	**29%**
	Rear End (DCA 130 – 132)	8%	8%	8%	12%
	Lane Change & Side Swipe (DCA 133 – 137)	6%	**13%**	**15%**	11%
Speed Zone	50km/h	19%	**38%**	8%	17%
	60km/h	**50%**	**50%**	**77%**	**55%**
	70km/h	10%	4%	15%	9%
	80km/h	15%	4%	N/A	12%

Table A59: Summary of Crash Statistics at Unsignalised Intersections by Intersection Geometry

Characteristic		Unsignalised Intersections			All Intersections
		Cross Intersections	T-Intersections	Multiple / Complex Intersections	
Number of crashes in 5 year period		420 (31%)	921 (67%)	20 (1%)	2104
Crash Severity	Fatality	3%	4%	5%	3%
	Serious Injury	51%	48%	55%	47%
	Other Injury	46%	48%	40%	50%
Weather	Wet	8%	8%	5%	8%
	Dry	92%	91%	95%	91%
Light	Day	70%	71%	85%	69%
	Dusk	12%	10%	10%	11%
	Dark	18%	19%	5%	20%
Behaviour	Vehicle Driver	79%	75%	80%	76%
	Motorcycle Rider	20%	24%	20%	22%
Predominant Crash Types	Cross Traffic (DCA 110)	**39%**	N/A	15%	14%
	Right Far (DCA 111)	5%	4%	10%	4%
	Right Near (DCA 113)	13%	**29%**	25%	18%
	Right Through (DCA 121)	**20%**	**27%**	5%	**29%**
	Rear End (DCA 130 – 132)	9%	11%	5%	12%
	Lane Change & Side Swipe (DCA 133 – 137)	7%	10%	35%	11%
	Pulling Out (DCA 152)	2%	6%	N/A	3%
Speed Zone	50km/h	21%	15%	10%	17%
	60km/h	**54%**	**55%**	**40%**	**55%**
	70km/h	5%	11%	N/A	9%
	80km/h	7%	12%	25%	12%

Investigation of Technologies to Reduce Motorcycle Crashes at Intersections

Part 2 – Final Report

<u>Client:</u>

VicRoads – Road Safety and Network Access

Revision	Job No	Date issued	Prepared by	Authorised by
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EXECUTIVE SUMMARY

This report is the second part of a two part investigation into crashes at intersections involving motorcycles (and motor scooters). Part One included interrogation of the VicRoads RCIS database to determine the crashes involving motorcyclists at intersections between 1 January 2003 and 31 December 2007. In addition the Police report for each crash was read to establish additional information about the crash.

Part Two investigates potential infrastructure and technology solutions to improve safety for motorcyclists at intersections, with consideration to the crash patterns investigated and established in Part One.

The suitability of the potential infrastructure and technology solutions for specific intersection types has been considered. Part One of this study highlighted the following most-common motorcycle crash scenarios:

- Cross traffic (DCA 110) at cross intersections
- Right through (DCA 121) at cross intersections
- Right near (DCA 113) at T-intersections
- Right through (DCA 121) at T-intersections
- The proportion of crashes at cross intersections was approximately the same for intersections with and without traffic signal control
- The proportion of crashes at T-intersections was significantly higher at unsignalised intersections than at signalised T-intersections (probably due to the provision of these across the network)

Part Two of the study included a literature review of Australian and overseas literature relating to intelligent transport systems (ITS) applications for motorcycles. This showed there has not been significant research in this area, except in Japan (Honda). The literature review was extended to ITS applications which could be adapted to motorcycles. Much of the ITS literature relates to vehicle-to-vehicle communication applications, whereas the aim of this study was to investigate vehicle-to-infrastructure communication applications. Consultation with Australian and overseas experts in road safety was conducted to investigate research underway and not yet reported. Consultation was also conducted with industry representatives of suppliers for the infrastructure and technology solutions. The combination of the literature review and the consultation has guided the recommendations within this report.

Infrastructure solutions include elements to slow vehicles down to reduce the likelihood of a crash, and the severity. In addition, infrastructure solutions can include the provision of adequate sightlines at intersections (the MAIDS study[1] showed that half of all motorcycle crashes at intersections were attributed to poor visibility). The solutions may include the provision of roundabouts at intersections, and lower speed environments to encourage lower vehicular speeds. The approaches to roundabouts should be clear of obstructions and have appropriate approach angles. Too high an angle may lead to excessive deceleration on the approach and may lead to rear-end collisions, whilst too low an angle may lead to a motorcycle being hidden from the view of drivers of other vehicles.

The geometry of intersections should maximise sightlines and reduce vehicle speeds. In addition, a smooth braking surface should be provided at intersections, and intersections positioned on straight sections of road. Street furniture, trees and fences should be located to not impede on sightlines on the approach to and within the intersection, and be located a few metres from the edge of the road so they are less likely to be struck by an errant rider.

With regard to intersection control, 26% of all motorcycle intersection crashes occurred at signalised intersections, whilst 65% occurred at unsignalised intersections, and 9% occurred at roundabouts.

At intersections with traffic signal control, the most common crash type is right through (DCA 121). At roundabouts the most common crash type is cross traffic (DCA 110). At unsignalised intersections, the most common crash type is right near (DCA 113) and right through (DCA 121).

The crash scenarios investigated with regard to potential infrastructure or technology solutions to improve rider safety are summarised in Table 1.

[1] *ACEM, "MAIDS In-Depth Investigations of accidents involving powered two wheelers, Final Report 2.0"*, April 2009

Table E1: Infrastructure & Technology Solutions for Motorcycle Crash Types

Motorcycle Crash Type	Infrastructure & Technology Solutions
Right through crashes at traffic signal controlled cross intersections	a) Extend all red phase b) Extend red signal phase on one approach c) Fully control right turns d) Vehicle activated sign (VAS) or Variable message sign (VMS) warning to other drivers of approaching motorcycle
Right through crashes at traffic signal controlled T-intersections	a) Extend all red phase b) Extend red signal phase on one approach c) Fully control right turns d) VAS or VMS warning to other drivers of approaching motorcycle
Right through crashes at unsignalised T-intersections	a) Improve sightlines & reduce vehicle speeds (e.g. construct roundabout) b) VAS or VMS warning to other drivers of approaching motorcycle
Right near crashes at unsignalised T-intersections	a) Improve sightlines & reduce vehicle speeds (e.g. construct roundabout) b) VAS or VMS warning to other drivers of approaching motorcycle
Cross traffic crashes at unsignalised cross intersections	a) Improve sightlines & reduce vehicle speeds (e.g. construct roundabout) b) VAS or VMS warning to other drivers of approaching motorcycle
Cross traffic crashes at roundabouts	a) Improve sightlines & reduce vehicle speeds b) VAS or VMS warning to other drivers of approaching motorcycle

The system requirements for each vehicle detection and classification option were investigated, and the costs associated with the supply and installation of the options, including system integration where required, and the ongoing annual maintenance costs. Estimated BCRs range from less than 1.0 to 14.11 for sites with two motorcycle crashes, and is dependent on the cost of the solution, the number and severity of motorcycle crashes at the site, and the speed zone.

The recommendation is to trial motorcycle detection at a T-intersection with a high number of motorcycle crashes, where geometric and sightlines improvements cannot be made, and the alternatives listed in Table 1 cannot be provided. In addition to the motorcycle detection, the trial should include the provision of vehicle activated signs on two approaches to warn other drivers of an approaching motorcycle, to reduce the number of right through (DCA 121) and right near (DCA 113) crashes involving other drivers failing to see approaching motorcyclists.

A trial conducted at a T-intersection will be more cost effective to implement, as there are fewer approaches. At a cross-intersection, all four approaches may require motorcycle detection and vehicle activated signs, unless there is a trend of crashes on only one or two approaches. Therefore a trial at a T-intersection would be cheaper to install, and monitor the effectiveness and safety benefits, than at a cross-intersection. If the trial is found to successfully reduce the number of motorcycle crashes, it could then be introduced at cross-intersections as well as T-intersections.

Due to the high installation and maintenance costs associated with the provision of motorcycle detection and vehicle activated signs, these measures should be the last option, when other alternatives are not possible to achieve.

TABLE OF CONTENTS

INTRODUCTION

Trafficworks was engaged by VicRoads – Road Safety and Network Access to investigate patterns and types of motorcycle crashes at intersections, and infrastructure and technology solutions to reduce these crashes.

Part One of the Study included interrogation of the VicRoads RCIS database to determine the crashes involving motorcycles and motor scooters at intersections between 1 January 2003 and 31 December 2007. In addition the Police report for each crash was read to establish additional information about the crash.

Part Two investigates infrastructure solutions and technologies to improve safety for motorcyclists at intersections, with consideration to the crash patterns investigated and determined in Part One. Part Two includes a literature review, a summary of consultation with overseas contacts and industry representatives.

Throughout this report, the term "motorcycles" is used to represent all powered two-wheelers.

This report includes a literature review of ITS applications for motorcycle safety and studies into motorcycle crashes. Consultation was undertaken with local and overseas experts in the field of motorcycle and road safety, as well as industry representatives with regard to options for motorcycle detection and the provision of warnings to other drivers of approaching motorcyclists. The feasibility of potential infrastructure and technology solutions is investigated, and the suitability for various intersection types and motorcycle crash scenarios. The system requirements for the various technology solutions were investigated, and the supply and installation costs of the options estimated, as well as annual maintenance costs. Recommendations for trial sites are provided to review the safety benefits from the technology available.

LITERATURE REVIEW

Most of the research and literature relating to intelligent transport systems (ITS) is focused on vehicle-to-vehicle communications. For example, a vehicle is detected on the approach to an intersection, and a message is sent to the driver of another vehicle on the adjacent approach to warn them of an approaching vehicle. The warning is provided in a number of ways and can include verbal messages, text or graphical displays on the windscreen, or on a satellite navigation system display within a car. Warnings can be provided to motorcyclists via the rider's helmet (visual and audio).

Most of the research is concentrated on detection of all vehicles, but could be adapted to motorcycles, if necessary. In some instances it may not be necessary to restrict the use of technology to detect only motorcycles, but to include all vehicles, depending on the crashes to be addressed and other operational characteristics of the intersection.

A summary of the literature review is provided below, with references related to motorcycle safety or ITS infrastructure, separated sections by country / region.

The three major initiatives are:

- Smartway, in Japan, which utilises units within vehicles to communicate with roadside furniture and other vehicles.
- VII (Vehicle Infrastructure Integration), in the USA, which included a road test of the system in the suburbs of Detroit.
- PReVENT, in Europe, which applies to a group of joint public-private R&D projects that are being implemented for accident reduction.

Australia

1. Bayly M, Regan M, Hosking S, *"Intelligent Transport Systems and Motorcycle Safety"*, Monash University Accident Research Centre, July 2006

This study included a literature review and contact with individuals within Australia and abroad, to determine the level of ITS technologies available for motorcycle safety. This review found there was very little literature available, and little research into development of ITS applications for motorcycles that included infrastructure solutions.

The study outlined a number of in-vehicle and other vehicle ITS applications, including the "Motorcycle Detection System", which alerts other drivers of the presence of the motorcycle, but does not provide speed information that the inter-vehicle communication systems provide (developed by Honda, Suzuki and Yamaha in Japan). Similarly, these systems do not provide feedback to the rider about the presence of the other vehicle (as the inter-vehicle communication systems can provide). The study advises that the motorcycle emits a weak signal from a transmitter mounted on the vehicle, which is detected via receivers on the front and rear of other vehicles. The driver is informed of the motorcycle through auditory and visual displays. This technology is limited by the uptake of transmitters and receivers. The study outlined a number of infrastructure based ITS applications, including "Variable Message Signs", used to convey messages to drivers and riders, such as indications of traffic congestion, crashes ahead, upcoming road works, and weather conditions.

2. Regan M, Oxley J, Godley S, Tingvall C, *"Intelligent Transport Systems: Safety and Human Factors Issues"*, Monash University Accident Research Centre, prepared for the Royal Automobile Club of Victoria (RACV), September 2000

This report was commissioned by the RACV to assess the safety and human factors implications of intelligent transport systems for Victorian road users, including both in-vehicle and out-of-vehicle intelligent transport systems (ITS), although the emphasis was on in-vehicle systems as these were considered to provide the greatest potential safety benefits. In addition the potential safety benefits for high risk and vulnerable road users (in particular young novice drivers, older drivers, pedestrians, motorcyclists, bicyclists and cultural minorities) were investigated.

Human factors issues relevant to ITS applications include:

a) System reliability (human responses to system failure and false alarms)

b) Human machine interface (to minimise distraction and cognitive workload)

c) Behavioural adaptation (how people adapt over time to exposure to the systems and how acceptable they find the systems)

The report notes that very few ITS applications have been developed specifically for motorcyclists.

3. Australian Dedicated Short Range Communications (AusDSRC), see website http://ausdsrc.com.au/index.html

AusDSRC is an industry driven group, seeking to allocate the 5.9GHz radio frequency spectrum for dedicated short range communications (DSRC) and act as a catalyst for intelligent transport systems (ITS) applications. This would be consistent with the USA and Europe, with the aim to achieve globally agreed standards and interoperability. DSRC is a radio technology that combines GPS and Wi-Fi like communications to effectively enable cars to talk to each other (Professor Alex Grant, Director of UniSA's Institute for Telecommunications Research). Dedicated short range communications is emerging as the communications standard for future ITS applications, and will allow for vehicle to vehicle and vehicle to infrastructure communication. On-board processing units are required within vehicles. A large scale trial is proposed for Adelaide.

4. Cairney P (ARRB), Ritzinger A (ARRB), *"Motorcyclists' view of advanced technology for motorcycle safety"*, Australasian Road Safety Research Policing Education Conference, 2008, Adelaide, South Australia, November 2008

5. Cairney P (ARRB), Ritzinger A (ARRB), *"Industry and rider views of ITS for safer motorcycling"*, Australasian Road Safety Research Policing Education Conference, 2008, Adelaide, South Australia, November 2008

These papers outline research conducted by ARRB for VicRoads about the feasibility of intelligent speed adaptation (ISA), automatic crash notification (ACN) and advanced braking systems, which includes anti-lock braking systems (ABS), linked braking systems and emergency brake assist (EBA) for motorcycles. The study included discussions with nine experts in motorcycle safety / vehicle systems, and eight rider focus groups with riders of different ages and experience. All of the ITS applications investigated were expected to have positive impacts on motorcycle safety experts interviewed independently from the motorcyclists. Riders were generally more skeptical. They accepted that ACN would have safety benefits for a small number of riders, they were not convinced that ISA or advanced braking systems would have safety benefits. Riders thought that whether or not advanced braking systems appeared to be good value for money depended on the value of the motorcycle.

Japan

6. Arino M (Road Bureau, Ministry of Lane, Infrastructure, Transport and Tourism, Government of Japan), *"ITS Policy in Japan and Smartway"*, published on website http://www.mlit.go.jp/road/ITS/topindex/topindex_g07_2.html

Japan started developing Smartway in 1995. Smartway includes in-vehicle units and roadside infrastructure to communicate messages to drivers to reduce travel time and congestion and to improve road safety. Smartway is based on Vehicle Information and Communication System (VICS). By December 2008, over 33.9 million car satellite navigation systems and on-board units had been sold. Out of the vehicle fleet of 70 million vehicles, this represents a high take up.

Communication is two-way between the vehicle and the roadside. The roadside sensor sends information on congestion to the vehicle, and the vehicle sends information on vehicle speed and identity to the central computer systems. The central computer systems use the information to detect and predict congestion. The in-vehicle devices also receive information over FM radio channels via distinctive FM antennae. The uptake of the in-vehicle units is high as noted above.

The units also facilitate electronic tolling. Communication includes messages to LED signs to encourage vehicles to slow down in congested conditions, lane choice information, advanced cruise-assist highway system (AHS), and information on travel conditions on mountain passes onto the internet.

Smartway test locations include:

a) Meishin Expressway and New Meishin Expressway, Kyoto, Osaka and Kobe – providing information on obstacles ahead via highway radio reports

b) Hanshin Expressway, Kyoto, Osaka and Kobe – preventing hazards on entering curves, providing information on obstacles ahead, merging assistance, and providing information on conditions ahead (providing road information by still images)

c) Sanyo Expressway, Hiroshima – calling attention to drivers when they are exceeding the speed limit

d) Nagoya Expressway, National Highway 153 and Tokai – Kanjo Expressway, Aichi – providing information on obstacles ahead, preventing hazards on entering curves, providing information on conditions ahead, and internet information access

e) Metropolitan Expressway, Tokyo – providing information on obstacles ahead (coordinated service for expressways and ordinary roads). Providing information on conditions ahead (by still images)

f) Kan-Etsu Expressway, Niigata – collecting vehicle behavior information (snow covered road surface information)

g) National Route 191 in Samni district of Hagi City (service started in April 2005) indicates on a variable message sign if a vehicle is approaching in the opposite direction. This has reduced lane deviation and vehicle collisions (to none since implementation).

h) Yamada Service Area (outbound) on the Oita Expressway detects vehicles travelling in the wrong direction and uses alarms and flashing lights to immediately warn drivers travelling the wrong way.

In the past, roadside equipment such as traffic counters collected the traffic information, however as more vehicles have satellite navigation systems and on-board units, these can be used in conjunction with roadside probe data to collect the traffic data, as well as provide the warnings to drivers.

7. Asanuma N, Kawai M, Takahashi A, Shigenari R, Ochi K, *"Intelligent Technologies of ASV (The research and development of ASV-2 in Honda)"*, Honda, undated; and

8. www.world.honda.com/news/2008

Research at Honda has concentrated on vehicle-to-vehicle communication systems, as it develops cars as well as motorcycles. Four experimental vehicles were developed:

a) Car for research on reducing driver load and rear-end collision in congested conditions (lane keeping, automatic braking dependent on headway to vehicle in front)

b) Car for research on protecting pedestrians and motorcycle riders (car with infrared cameras to detect pedestrians at night, active headlight system, and inter-vehicle communication system)

c) Motorcycle for research on active safety (inter-vehicle communication system)

d) Motorcycle for research on passive safety (air bag).

The inter-vehicle communication system between cars and motorcycles works via satellite communication between the vehicles which are fitted with antennae and sensors that locate the GPS location of each vehicle. Within the car, a warning display is provided to the driver of an approaching car or motorcycle if a potential collision could occur. The display is provided on the satellite navigation system, and a head up display within the car. Warning messages are provided to the motorcycle rider via a head up display within the helmet and an audio message. Whilst the system has potential, it relies on all vehicles being fitted with the equipment to enable the inter-vehicle communication.

9. Presentations by Moriyama S, "ITS Advancement in Road Systems: Smartway", Ministry of Land, Infrastructure and Transport, Government of Japan, October 2006 (www.smartway2007.jp/) and Assano T, "TS051 Effectiveness if Road-Vehicle Cooperative and Infra-Only Safety System", Ministry of Land, Infrastructure and Transport, Government of Japan, October 2006.

Four Government Agencies joined in 1996 to promote ITS Smartway – defined as a "road system that allows the exchange of various types of information among cars, drivers, pedestrians and other users".

This includes cooperative safety systems that allow vehicles to obtain information from infrastructure devices using wireless communications to enable the driver to respond to traffic conditions beyond the range of what can be detected from a vehicle.

Chugoku Regional Development Board implemented measures at two sites – warning of oncoming vehicle information in an area of poor visibility (bend) to reduce head-on and passing collisions. The warnings were provided to drivers on roadside information boards.

The second was for standing, slow moving vehicles, where the infrastructure detects the presence of standing or slow moving vehicles in an area of poor visibility, and displays warnings to drivers on roadside information boards. This reduced rear end collisions in traffic congestion.

In both cases, infrastructure is used to detect the oncoming vehicle (by camera) and the warning provided on a variable message sign (VMS).

Studies found that the provision of information through road and vehicle cooperation and countermeasures immediately prior to an accident are approximately 90% effective against delays in recognition, whereas roadside information boards was effective for only 50%, e.g. detection of traffic congestion / queued vehicles ahead – message to an in-vehicle display and VMS display for those vehicles without in-vehicle units. Trials on the Metropolitan Expressway, Route No. 4 in Sangubashi, Japan indicate significant reductions in crashes following the introduction of the measures.

10. *"ITS A Collection of Effectiveness Case Studies: 2007 – 2008"*, ITS Promotion Office, Road Administration Division, Ministry of Land, Infrastructure, Transport and Tourism, ITS Planning and Promotion Office, Japan Institute of Construction Engineering

This brochure documents the effectiveness of a number of ITS applications throughout Japan, implemented to reduce traffic congestion, reduce carbon dioxide emissions by the use of electronic toll collection (ETC) systems, improve road safety by providing real-time information to drivers, and revitalize regional areas. With regard to road safety, the systems implemented included:

- Web based information for drivers about the condition of mountain pass roads and other locations during winter months together with tourist information to support plans for driving during winter.

- Real time warnings using an information board (VMS) indicating an approaching vehicle, on National Route 191 in the Sanmi district of Hagi City. If a car is approaching the board displays "Car approaching in opposite lane", and if no vehicles are approaching, the board displays "Curve ahead. Drive with Care". Vehicle collisions were eliminated, and lane deviations were reduced by at least half for both directions of travel (as noted above).

- Real time warnings using an information board to prevent wrong-way travel on a one-way exit ramp from the Oita Expressway. Two vehicles were detected to travel the wrong way on the ramp during the 32 day test period; both stopped and reversed.

Whilst not directly implemented for motorcyclists, their use could be adapted for this.

11. Ohouchi H (ITS Division, Research Centre for Advanced Information Technology, NILIM[2]), and Nagata K, Sekimoto K (AHS Research Association IHI Laboratory), *"Development of Laser Road Sensors"*, Japan, undated.

This report documents the test results of laser road sensors developed to detect and track vehicle and pedestrian behavior at intersections, including motorcycles passing in between vehicles, to support the development of technology to prevent right turn collisions and cross type collisions. The laser road sensor comprises a laser sensor head and a signal processing unit. The laser sensor head looks like a camera, and is mounted on a pole. The laser road sensor scans in two dimensions, converts the measured data (distance, horizontal angle, vertical angle) into three-dimensional plane coordinates, and detects data that has a height with reference to the road surface. The speed of the moving vehicle or pedestrian can be measured. The system can differentiate between vehicle type, and performs equally well in poor weather and night time conditions.

[2] National Institute for Land and Infrastructure Management of the Ministry of Land, Infrastructure and Transport

12. Okamoto T (Traffic Management & Control Division, Traffic Bureau, National Police Agency, Tokyo), Yamashiro Z (Traffic Management & Control Division, Traffic Bureau, National Police Agency, Tokyo), *"Traffic Management through ITS application for Changeable Social Needs",* undated

This reports calls for ITS applications to accommodate older drivers, with consideration to the aging Japanese population. The Agency is developing a Driving Safety Support System to include:

a) Warning function of the change of a traffic signal indication using two-way communication between an in-vehicle unit and infrared beacons installed near signalised intersections.

b) Green light extension to extend the green signal for elderly or slow moving pedestrians crossing the road.

c) Protection function for pedestrians whereby pedestrians are detected crossing the road, and warnings are provided to approaching drivers making a left or right turn via a display board / sign.

d) Accident prevention function at non-signalised intersections involving providing warning for a driver approaching an intersection via an in-vehicle unit and infrared beacons installed at non-signalised intersections where visibility is poor.

e) Accident prevention function when making a right turn involving detecting a motorcycle that may not be visible approaching from the opposite direction using a camera and providing warning to the driver of the approaching motorcycle.

Vehicle detection can be via a number of methods as follows:

a) Ultrasonic vehicle detectors – ultrasonic sensor heads intermittently emit waves directed at the surface of the road. Vehicles are detected by comparing the time difference between waves reflected from vehicles and waves reflected from the road surface.

b) Radar vehicle wave detectors – radar transceivers project microwaves in the direction of moving vehicles. Vehicles are detected by measuring their speed from the change in frequency of the waves resulted from them.

c) Infrared vehicle detectors – infrared vehicle detector heads emit infrared beams in the direction of the road surface. Vehicles are detected by comparing vehicle and road surface reflected beams. These detectors are also used in two-way communication with in-vehicle units.

d) Image processing vehicle detectors – these detectors film moving vehicles in multiple lanes using cameras. Image processing detects vehicles, measures vehicle speed and records vehicle type.

The report advocates use of more developed / intelligent vehicle detectors to allow for more intelligent uses in other areas of traffic management and safety. However these systems typically cost more, and the potential benefits and future use should be considered.

Europe

13. Crundall D, Clarke D, Ward P, Bartle C, *"Road Safety Research Report No. 85 Car Drivers' Skills and Attitudes to Motorcycle Safety: A Review"*, Department for Transport: London, May 2008

This study investigates whether a driver looks at a motorcyclist, realises it is a motorcyclist, and then correctly decides whether the motorcyclist presents a hazard. The report argues that drivers can look at, but not perceive a motorcyclist, due to the space that a motorcyclist takes up compared to a vehicle, but also to expectations and previous exposure. Drivers who are riders and those with family members that are riders have been found to have fewer collisions with motorcyclists, and have better observation skills in regard to motorcyclists.

14. *"How Close is Too Close? Concerning Car Collisions and Motorcycles"*, Motorcycle Action Group (UK), May 2006

This report documents the findings of an investigation of the cause of accidents involving cars and motorcycles at T-intersections, in particular Right of Way Violations (ROWV) where the other driver typically fails to give way to the motorcyclist. In fact 38% of motorcycle crashes investigated in the West Midlands involved ROWV, but less than 20% of these involved a motorcycle who was rated as either fully or partly to blame for the accident. This is noted to support the Department for Transport (DfT) 2004 casualty data by identifying that "The majority of ROWVs occur at T-junctions, which are three times as common as roundabouts or crossroads." The DfT report highlights that over 65% of ROWV accidents where the motorcyclist is not regarded as to blame involve a driver who somehow fails to see a motorcyclist who should be in clear view. The Motorcycle Action Group report highlights a number of possible reasons why other drivers do not recognise motorcyclists, including the size and conspicuity of motorcyclists, and their movement on approach to the intersection relative to the background (referred to as camouflage and looming).

The report recommends that drivers are trained to be more aware of motorcyclists, and that riders are better to trained to avoid collisions in these circumstances (when the driver often brakes in the middle of the intersection upon seeing the approaching motorcyclist). In addition, car manufacturers are requested to minimise the creation of blind spots at front and middle pillars. The authors also call on the need for better data collection about crashes and near misses.

15. *"IHIE Guidelines for Motorcycling, Improving Safety Through Engineering and Integration"*, Institute of Highway Incorporated Engineers (UK), Version 1.1

Chapter 4 includes road design and traffic engineering guidance to improve motorcycle safety. In particular, with regard to priority junctions and roundabouts, the document recommends the optimisation of sightlines and provision of good braking surfaces for all road users. This will mitigate the problem of drivers not recognising motorcyclists, including when they have priority. Low entry angles on roundabout approaches mean riders in the circulatory area can be obscured by the central pillar on cars. Entry angles that are too high can lead to excessive speed on the approach and tail-end collisions. Wide entries encourage drivers to pull up on the offside of the rider, especially if the latter is on a low-powered machine. The document also cites the importance of the positioning of street furniture and vegetation at intersections in affecting sightlines.

Additional recommendations for good design include:

- Allowance for motorcyclists to brake and stop while upright, travelling in a straight line and on a consistent grip surface
- Clear sightlines to pedestrian crossing facilities minimises the need for last minute braking or swerving. This means keeping formal crossing facilities away from bends where possible
- Consistent skid resistance, including coloured surface patches, especially on the approaches to intersections where motorcyclists may need to brake
- Use of high friction surfacing at intersections with a history of drivers emerging against priority into the path of motorcyclists (to maximise the rider's chance of braking safely)
- Termination of high friction surfaces on straight sections. Sudden changes in road surface, especially skid resistance, at intersections can lead to stability problems
- Avoid using different surfaces (e.g. granites setts and paving) to emphasise a change in circumstances at turning points such as intersections and roundabouts where motorcyclists may be destabilised
- Careful consideration of the location of road markings, especially within steering or braking zones. Used inappropriately, they can force riders off the safest line, or if poorly designed or laid, can collect and divert water. Blacking out redundant line marking rather than burning or planing creates reduced skid resistance
- Positioning of street and roadside furniture should be considered, with regard to sightlines and impact characteristics when struck by a sliding body in the event that the rider comes off the motorcycle.

Areas being investigated to improve motorcyclist safety in the UK include:

- Shared use of advanced stop lines (with cyclists)
- Shared use of bus lanes.

16. ACEM, "MAIDS In-Depth Investigations of accidents involving powered two wheelers, Final Report 2.0", April 2009

The powered two wheeler (PTW) accident data collected in this study indicated that the object most frequently struck in an accident was a passenger car. The second most frequently struck object was the roadway itself, either as the result of a single vehicle accident or of an attempt to avoid a collision with another vehicle. Whilst each sampling area contained both urban and rural areas, the majority of the accidents took place in an urban environment.

Travelling and impact speeds for all powered two wheeler categories were found to be quite low, most often below 50 km/h. There were relatively few cases in which excess speed was an issue related to accident causation.

The cause of the majority of PTW accidents collected in this study was found to be human error. The most frequent human error was a failure of the driver of the other vehicle to see the powered two wheeler within the traffic environment, due to lack of driver attention, temporary view obstructions or the low conspicuity of the powered two wheeler. Half of all crashes involving powered two wheelers at intersections occurred at intersections with poor visibility being an important contributing factor.

Exposure data indicated that whilst scooters represented the majority of accident cases, scooters were not over-represented in accidents in comparison with their presence. When the accident riders were compared to the exposure population, the data demonstrated that the use of alcohol increased the risk of being in an accident, although the percentage was lower than in other studies. Unlicenced powered two wheeler operators who were illegally riding powered two wheelers that required a licence, were also found to be at greater risk of being involved in an accident when compared to licenced powered two wheeler riders.

17. European Transport Safety Council, "Vulnerable Riders, Safety implications of motorcycling in the European Union", Brussels 2008

This report reviews accident statistics within the MAIDS report (above) and the Hurt report (see next Section). With regard to motorcycle vehicle safety measures, it refers to:

- Braking systems
- Conspicuity
- Speed limiters
- Secondary safety measures including helmets, protective clothing, airbags and leg protectors, protective cages
- Measures involving other road users including blind spot mirrors, A-pillar design, side protection on trucks

The report outlines road user behaviour including rider training, rider licencing, driver training, and enforcement.

The report includes review of and recommendations for road design and traffic engineering, as follows:

- Intersections and roundabouts - Roundabouts should have appropriate approach angles - too high an angle may lead to excessive deceleration on the approach and may lead to rear-end collisions, whilst too low an angle may lead to a motorcycle being hidden from the view of drivers of other vehicles.

- Road safety features should be located a few metres from the edge of the road (motorcyclists seldom end up far from the edge of the road after coming off their motorcycle). In addition vehicular speeds in urban areas should be reduced.

- Road building and maintenance – ensure a consistent road surface with proper skid-resistance is provided and maintained, and roads are kept clear of rubbish and debris, and visibility is maintained particularly at intersections.

- Signs and road markings – the use of warning signs for motorcyclists in high risk areas.

- Road safety audit and inspections.

18. *PreVent (www.prevent-ip.org)*

The Integrated Project PReVENT is a European automotive industry activity co-funded by the European Commission. The aim of the project is to develop and demonstrate preventive safety applications and technologies. Preventive safety applications help drivers to avoid or mitigate an accident through the use of in-vehicle systems which sense the nature and significance of the danger, while taking the driver's state into account.

Depending on the significance and timing of the threat, the active and preventive safety systems will:

- *inform* the driver as early as possible;

- *warn* him or her if there is no driver reaction to the information; and

- *actively assist or ultimately intervene* in order to avoid an accident or mitigate its consequences.

Preventive safety makes use of information, communications and positioning technologies to provide solutions for improving road safety. The technology can operate either autonomously on-board the vehicle or co-operatively based on vehicle-to-vehicle or vehicle-to-infrastructure communication.

One of the applications being investigated is INTERSAFE which is specifically designed for intersections. A test vehicle is being developed to provide warnings to the driver based on the location of the vehicle using on-board sensors, road markings and posts used for relative localisation within the intersection, detection, classification and path prediction of all other objects at the intersection, communication with traffic signals, and high level map information. The project includes driving simulations to test the effectiveness of the system.

19. Schulze M (Daimler AG), Makinen T (VTT), Irion J (Irion Management Consulting), Flament M (ERTICO-ITS Europe), Kessel T (EICT), *"PReVENT, IP Deliverable, IP_D15: Final Report"*, 7th May 2008

One of the goals of PReVENT is to speed up the market introduction and penetration of advanced safety systems and to overcome the major barriers for wide take-up of intelligent vehicle technologies.

Sensors being investigated include radar, laser, and 2D/3D-camera. Sophisticated wired and wireless communication technologies and modular vehicle system functional architecture and sophisticated software offer a lot of potential for enhanced safety.

The report states that the actual deployment of Intelligent Vehicle Safety Systems (IVSS) is still limited partly due to lack of public awareness on the benefits of these systems. The estimated safety impacts of the developed systems vary. The highest benefits were found for collision mitigation and vulnerable road users protection systems followed by lateral area safety systems and systems for cooperative and proactive driving. The results are not based on real accident figures, but on testing of demonstration vehicles.

One of the applications is the Intersection Driving Support System (INTERSAFE). Intersections are major accident black spots accounting for 30 % to 60 % of all injury accidents. The development of advanced sensor systems and algorithms can provide a solution by accurately locating the vehicle and path prediction of other road users. Combining this with signal status communication, it is possible to warn the driver of potentially hazardous situations.

The laser scanner system and a vision sensor in combination with a high-level map including landmarks were used for the localisation of the host-vehicle relative to the intersection. Based on the highly accurate host-vehicle localisation and the geometry of the intersection stored on the high level map, a background elimination process was carried out. From the current laser scanner data, all measurements of background objects at road sides were erased. As a result of this process, the remaining laser scanner data represented the road users (foreground) present at the intersection.

Different sub-systems and functions were developed as part of the INTERSAFE concept:

- Vehicle to Infrastructure Communication (V2I) to allow bidirectional V2I communication between the vehicle and traffic lights.
- Accurate relative localisation using a video camera system enabled the lateral and longitudinal position of the intersection features to be detected. Line matching and tracking algorithms were employed to compare measurements with a detailed "feature-level" map of the intersection markings, enabling the relative position of the vehicle in the intersection to be determined.
- Relative localisation at an intersection: the relative localisation of the host-vehicle was provided by using a laser scanner system and a vision sensor by comparing current measurements with landmarks in a high-level map.
- Detection, tracking and classification of road users were based on the host-vehicle localisation and geometry of the intersection stored in the high-level map and a performed background elimination process.

Even though these tests made a good start for further development processes, the practical realisation was only at a prototype level. Fully functional cooperative systems need high penetration rates regarding infrastructure and vehicles. Purchasers' willingness to pay for these systems has not yet been tested.

Currently available sensors employed for the dynamic surveillance of the vehicle environment provide neither the degree of reliability and robustness, nor the overall availability of the perceptual output that would be required for safety critical applications. Further development of vehicle detectors is underway.

20. Bellati A, Cossalter V, Lot R, Ambrogi A, *"Preliminary investigation on the dynamics of motorcycle fall behavior: influence of a simple airbag jacket system on rider safety"*, Conference paper from Forschungshefte, No. 12, 2006, p 219-243, Essen, Germany

This paper investigates the applicability of airbag technology developed for cars for motorcycle riders, including a study and modeling of how motorcyclists fall from their motorcycles.

USA

21. Hurt HH, Ouellet JV, Thom DR, *"Motorcycle Accident Cause Factors and Identification of Countermeasures, Volume 1" Technical Report"*[3], Traffic Safety Centre, University of Southern California, Los Angeles, California, January 1981

This report documents the detailed investigation of 900 motorcycle crashes, with the aim of determining the causes of motorcycle crashes and injuries to define the contributions of the rider, car driver, roadway features and motorcycle equipment. The second aim of the study was to determine the effectiveness of safety helmets and other protective rider equipment, and the third to determine countermeasures to prevent motorcycle crashes and reduce injuries.

The study found strong support for the use of daytime running lights to increase the conspicuity of motorcycles in traffic. The most common motorcycle accident involved another vehicle causing the collision by failing to give way to the motorcyclist at an intersection, usually by turning left in front of an oncoming motorcycle not seen by the driver[4]. In addition, the rider typically lacked skill and traffic strategy to avoid the collision. The study supports the use of safety helmets for riders, and better training and licensing for riders to avoid a collision.

22. Bellomo-McGee Incorporated under contract to Battelle, *"Intersection Collision Avoidance Study"* prepared for the US Department of Transport, Federal Highway Administration, FHWA Safety Office, Washington, September 2003

This report investigates infrastructure-only *Intersection Collision Avoidance Systems* (ICAS) concepts that are complementary to in-vehicle autonomous and vehicle/infrastructure cooperative concepts aimed at reducing the number of crashes at intersections. The study

[3] Often referred to as the "Hurt" report
[4] Where they drive on the right side of the road, so equivalent to a DCA 121

included a review of crash data at intersections (signalised and unsignalised), a review of existing intelligent crash countermeasures and a review of human factor studies to determine issues that will affect and influence the selection and design of infrastructure-based collision countermeasures.

The report refers to a number of intersection collision avoidance systems as follows:

- Minor road intersection warning
- Major road intersection warning
- Left turn / oncoming traffic warning[5]
- Dilemma Zone Control – signalised intersection

The major and minor road intersection collision warnings include detector loops installed on the major and minor roads to enable warning to be provided to drivers on all approaches. An example was installed in Prince William County, Virginia, where the detector loops on the major road approaches included pairs of two closely spaced loops that measure the vehicle speeds and activated a timer that controlled the activation length of the warning on the sign on the minor road approaches. Warnings signs on the major road were activated by vehicles approaching on the minor road, or stopped at the stop line. Detector loops are required on all lanes of the major and minor road approaches, and are located based on American Association of State Highway and Transportation Officials (AASHTO) sight distance values and / or the geometric design and design speed of the road.

Detector technologies are outlined to include the following:

- Microwave and millimeter-wave radar
- Pulsed-Doppler Ultrasound detector
- Active LED infrared radar
- Inductive loop detectors
- Video image detection systems
- Passive infrared detectors
- Magnetometer
- Piezo electric detectors
- Passive acoustic detectors.

The report also reviewed references to human factors studies, and notes that proposed new technologies should be tested to review the ability of drivers to understand the new and innovative technologies.

[5] DCA Type 121 for right turns in Australia

Concepts proposed for intersection collision prevention:

a) Dynamic left-turn[6] phase offset at signalised intersections

This concept is aimed to improve safety for a vehicle stored in the centre of the intersection waiting to turn left at the end of a green phase, and competing with approaching through traffic that travel through the intersection at the end of the amber / start of the red signal. This concept offsets the signal phasing of the turning motorist and the approaching through traffic by providing a longer amber time for the turning vehicle to turn. The approaching through vehicles face a red signal whilst the turning vehicle faces an extended amber signal. The system requires the following to warrant an offset with the traffic signal timing:

- A subject left-turning vehicle is detected in the intersection (right-turning in Australia)
- Opposite direction through traffic is present such that there is a potential conflict
- No opposite direction turning vehicle is present.

Vehicle detection can be via vehicle detector loops.

b) Violator warnings at signalised intersections

Violator warnings are dynamic systems aimed at warning drivers that appear to have missed a red signal to stop. They require detection of the vehicle, and a dynamic sign or flashing beacon adjacent to the red traffic signal to attract the driver's attention.

c) Cross traffic warning

This concept provides warning to right of way motorists if a vehicle facing a red signal is going to travel through the intersection without stopping as required.

d) Intersection collision warning for a left turn across path lateral direction (DCA 113, right-near in Australia)

This concept works by warning a stopped motorist on the minor road when it is unsafe to turn into the major road. Signage provided can include "vehicle approaching from left / or right", "vehicle approaching" or a symbolic representation of vehicle approaching on the major road.

e) Intersection collision warning for a left turn across path opposite direction (DCA 121, right-through in Australia)

Guidance is provided to the driver turning as to whether there is a sufficient gap available in the oncoming traffic to turn. The sign needs to be located in an easily recognizable device, and in the line of sight of motorists waiting to turn right.

Trials of Intersection Collision Warning systems and Violator Warnings were trailed at six intersections in the USA. However the effectiveness of the systems were estimated

[6] Right turn in Australia

based on reasonable motorist expectations (perception-reaction time, braking rate etc). No post-implementation analysis has been conducted.

23. Michigan Department of Transport *"VII[7] Michigan Program Concept of Operations - Stakeholder Presentation",* 7th October 2005;

24. Michigan Department of Transport, *"Michigan VII Update, July – September 2007"; and*

25. Michigan Department of Transport *"Line of Business Startegy for Vehicle – Infrastructure Integration, Part 1: Startegic and Business Plan"*, 30th June 2008

The VII program is a collaboration between the Michigan Department of Transport and a number of other public bodies, electronic and equipment manufacturers (including General Motors, Daimler Chrysler Corporation, Ford Motor Company and Nissan Motors North America), and communications carriers (Motorola and Azulstar Networks).

The system includes roadside communications, GPS locators, celluar communications, data processing centres and communication to drivers via the internet, in-vehicle units and roadside signs. Vehicles will be fitted with wireless broadband technology to have the ability to communicate with the roadside and receive real time messages about emerging traffic conditions while approaching unsafe intersections, traffic accidents, road construction and maintenance sites. Vehicles will be able to communicate with each other and send warnings to help coordinate maneouvers and increase safety. Traffic management operators will receive real time messages from vehicles and be able to monitor traffic conditions and respond immediately to traffic events. The technology will also permit vehicles to act as probes on the roadway and send back continuous information on pavement, weather and other location specific conditions.

The presentation highlights a number of issues to be resolved during testing:

- How to collect the data?
- Who / how to process the data?
- How to distribute the data, and to whom?
- Who / how to use the data?
- Responsibilities of each party
- Data access rights
- Data security
- Inter-agency / company agreements
- Competitive market issues

Testing was due to be completed in the Detroit test area by the end of 2008, however results are not yet available. This test involved dedicated test vehicles travelling on 75 miles of road. Fifty

[7] VII – Vehicle Infrastructure Integration

seven roadside wireless units were installed at key intersections and use dedicated short range communications to communicate with test vehicles. Information exchanged includes the timing of traffic signals, advisory information, and vehicle data such as speed, direction, and location.

26. Halladay M (Office of Safety, Federal Highway Administration, US Department of Transport (DOT)), *"Motorcycle Safety and Intelligent Transportation Systems"*, presentation prepared for the ITS World Congress, New York, 20th November 2008

This presentation notes that motorcycles have not been significantly represented as a distinct vehicle class within the US DOT ITS program. The presentation notes that it is difficult to mount integrated vehicle-based safety systems onto motorcycles due to the size of the units, but that units mounted in other vehicles are able to detect even the smallest motorcycles. Most ITS applications are designed for passenger cars and trucks, but some are adaptable to motorcycles.

CONSULTATION

A number of authorities on road and motorcycle safety were contacted to determine the latest research in the area of technologies to improve motorcycle safety at intersections. The following organisations were contacted for information:

- European Commission for Transport, Road Safety Unit
- UK Department for Transport
- Kuratorium fur Verkehrssicherheit, Department of Transport and Mobility, Project Manager Infrastructure and System Analyses, Germany
- SRA - the Swedish Road Administration, Traffic Safety Division
- Motorcycle expert in Denmark
- Motorcycle Action Group (MAG), UK
- British Motorcyclists Federation
- Federation of European Motorcyclists Associations (FEMA)
- Norway Road Traffic Authority
- Honda
- USA Department of Transport, Federal Highway Administration, Office of Safety
- Michigan Department of Transportation
- Centre for Accident Research and Road Safety, Queensland (CARRS-Q)
- Monash University Accident Research Centre (MUARC)

These organisations directed the study team towards information that is included within this report, or advised that no information or knowledge of information was available.

The Road Safety Unit of the European Commission was unable to provide information about any research being carried out in the European Union into technologies to reduce crashes involving motorcyclists at intersections.

An expert in Denmark advised that most motorcycle crashes in Denmark occur at cross road intersections, with drivers not seeing motorcyclists due to their size. The most common crash type is when the other vehicle turns left (driving on the right side of the road, so a DCA 121), and changing lanes (side swipe) when the motorcyclist is not seen in the driver's blind spot.

An expert from the Centre for Accident Research & Road Safety Queensland (CARRSQ) advised that a recent study in Brisbane included investigation of vehicle speeds by vehicle classification, which showed that the motorcycle detection was available using detector loops (based on the shorter wheel base of motorcycles). This would be a relatively simple installation and adaptation of existing technology. There may be some difficulty detecting only motorcycles, due to the wide variety of motorcycle sizes, masses and metal / plastic components, however even if bicycles are detected this will add to the safety of such a system. The expert also commented that motorcyclists are often reluctant to fit devices to their motorcycles due to a reduction in performance / riding characteristics or aesthetics. In addition, car drivers may be reluctant to fit devices to their vehicles to improve motorcycle safety if it involves additional cost.

Consultation with the Motorcycle Action Group (MAG) in the UK indicates that there is a common view among riders that most collisions with cars are the fault of the drivers, and a common view among policy makers that most actions to reduce collisions should focus on the rider. The Institute of Highway Incorporated Engineers (IHIE) and MAG believe that infrastructure and traffic management have a significant role to play in reducing risk for riders, alongside driver awareness and road-user skills in general. The geometry of intersections can often work against rider safety if features designed to slow traffic or manage flows also obstruct visibility of motorcyclists. There are a number of EU projects investigating the role of on-board technologies for motorcycle collision avoidance. The Department for Transport has conducted surveys into the applicability and acceptability of such technologies, which indicates that riders are generally unreceptive especially to any technologies that interfere with the throttle or brakes (due to a fear of over balancing). Even simple information systems, such as GPS-linked audible warnings / graphical representations of intersections and other infrastructure on the road ahead are generally seen as a distraction by riders.

Industry representatives were consulted with regard to the technology available for the solutions discussed in the next section. The industry representatives consulted are listed below, whilst the information obtained is summarised in the following sections by technology type:

- Xenon Technologies
- Metrocount
- MDL Australia
- Xtralis
- OSI LaserScan
- Q-Free Australia
- Trans Toll Australia
- Excel Technology
- A1 Roadlines
- Hi Lux Technical Services
- Axent
- CEOS Industrial Pty Ltd
- SEITA & ConnectEast
- VicRoads ITS Standards, Regional Services

FEASIBILITY OF POTENTIAL SOLUTIONS

A summary of the literature review and consultation, together with consideration of the feasibility and likely acceptability of the potential infrastructure and technology solutions is provided.

Infrastructure Solutions

Infrastructure solutions include elements to reduce the speed of all vehicles to reduce the likelihood of a crash, and the severity. In addition, infrastructure solutions can include the provision of adequate sightlines at intersections. The MAIDS study showed that half of all motorcycle crashes at intersections were attributed to poor visibility.

The solutions may include the provision of roundabouts at intersections, and lower speed environments to encourage lower vehicular speeds.

Roundabouts should have appropriate approach angles. Too high an angle may lead to excessive deceleration on the approach and may lead to rear-end collisions, whilst too low an angle may lead to a motorcycle being hidden from the view of drivers of other vehicles.

The geometry of intersections should maximise sightlines and reduce vehicle speeds. In addition, a smooth braking surface should be provided at intersections, and intersections should be located on straight sections of road, rather than curves, where motorcyclists would be required to brake whilst turning and leaning. Street furniture, trees and fences should be located to not impede on sightlines on the approaches to and within the intersection, and be located a few metres from the edge of the road so they are less likely to be struck by an errant rider.

All new intersections should be designed with consideration good design practices to cater for the needs of motorcyclists as well as pedestrians, cars, trucks and public transport vehicles. Review of existing intersections with motorcycle crashes should include a review of any hazards created by deficiencies in the intersection geometry, sightlines or the presence of roadside hazards. Amendments to these issues may address the crash problem, and may be more cost effective than the technology solutions discussed in the next section.

Technology Solutions

Motorcycle Detection and Classification

Options for motorcycle detection and classification include:

1. Detector loops and chassis, such as those by Excel Technology Group. This system requires the installation of two detector loops per traffic lane, spaced approximately 2-3m apart to reduce the likelihood of motorcycles passing between the loops. The loops can extend across the width of the lane to prevent motorcycles from missing the loops, or alternately the loops could be offset to detect the motorcycle passing over at least one loop (and therefore classifying it as a motorcycle). The roadside chassis would detect and classify motorcycles from other vehicles, and provide a serial contact output.

Detector loops are widely used throughout Victoria for vehicle detection. The proponents of other systems discussed do not consider that detector loops could accurately detect and classify motorcycles from other vehicles.

2. Radar vehicle wave detectors, such as the SDR radar classifier provided by A1 Roadlines, which detects and classifies vehicles by radar mounted on a pole beside the road, when installed in conjunction with detector loops. This system would operate satisfactorily in congested conditions. However A1 Roadlines is not aware of an existing software interface that could be used to provide real time information to another device, and so this would need to be developed.

3. Infrared vehicle detectors, such as the infrared traffic logger (TIRTL) by CEOS International which works by detecting vehicles passing through infrared beams that cross the road. This system works in free flowing traffic conditions, but will not work if vehicles are stationary or a vehicle parks such that it blocks the infrared beam. Therefore it could not be used in locations where kerbside parking is permitted, or within the typical queue length on an approach to the intersection. The system is used for toll gantry auditing and speed enforcement, and has a reported detection accuracy of 99.5%. This system will be able to detect motorcycles splitting lanes. This system could also be used to detect and classify bicycles as well as motorcycles. The TIRTL is an industrial PC, and no additional hardware or software is required to interface the TIRTL and a vehicle activated sign.

   The TIRTL pair units are installed perpendicular to traffic, and are typically installed into the kerb. TIRTLs have been installed at the following sites as an independent secondary device to corroborate speed detection at speed camera sites:

   - Geelong Road, Victoria (8 sites)
   - Hume Freeway, Victoria (10 sites)
   - Various intersection sites in Victoria (10+ sites)

   In addition, TIRTLs are installed at Safe-T-Cam sites in Braxton, Tweed Heads, Jones Island in NSW to classify heavy vehicles. TIRTLs are also installed at heavy vehicle checking stations in NSW to classify heavy vehicles for a weight station. A trial site is located at a railway level crossing site in Bagshot, Victoria, for speed and rail crossing offences.

   Discussions with VicRoads ITS indicate that the group does not support the use of infrared vehicle detectors outdoors.

Figure 1: TIRTL Operation

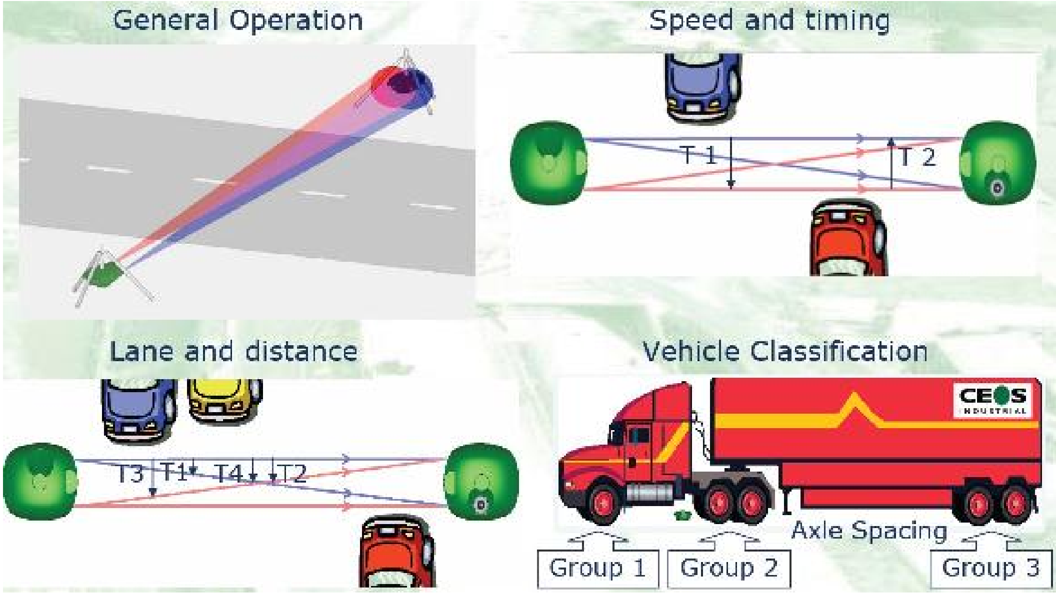


Figure 2: Diagram of TIRTL Installation

Figure 3: TIRTL Installation

Figure 4: TIRTL Installation with Solar Power

4. Laser vehicle detectors, such as Autosense offered by OSI LaserScan and Laser Ace offered by MDL Australia.

   The Autosense units utilise an eye-safe laser to scan the roadway and vehicles passing through the sensor's beam field. Each unit emits two scanning laser beams in order to create a 3D image of the vehicle. Data collected by the sensor is processed in real-time, transmitting its output within 25ms. The length, height and width of vehicles are used to classify vehicles. The speed of vehicles is measured from the number of scans from the vehicle appearing on the first beam until it appears on the second beam. The speed calculated at the front of the vehicles is used to calculate the vehicle's length.

   The units can cover one or two lanes. The two-lane unit has a wider field of view (30 degrees), but could miss detecting a motorcycle due to shadowing if it were adjacent to a heavy vehicle and if the motorcycle is travelling on the outermost part of the field of view. This could be overcome by the use of two single lane units (with a narrower field of view at 15 degrees) on two-lane roads (one unit mounted over each lane).

   The units are used in the Sydney Eastern Distributor interface to Cross City Tunnel, the main Cross City Tunnel, in the Lane Cove Tunnel and in the Sydney Harbour Tunnel.

Figure 5: Autosense Installation

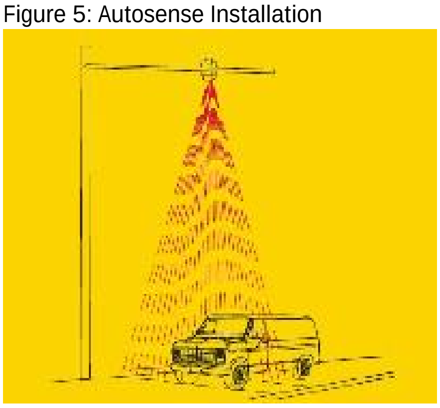


Figure 6: Autosense Device

   The Laser Ace IM system can be configured to output range, speed and height of vehicles, and may be set to trigger cameras in toll booths or law enforcement applications. However MDL has advised that the laser ace system would need to be installed with detector loops to be able to classify motorcycles, and that the system would not be able to compete financially with the use of detector loops alone.

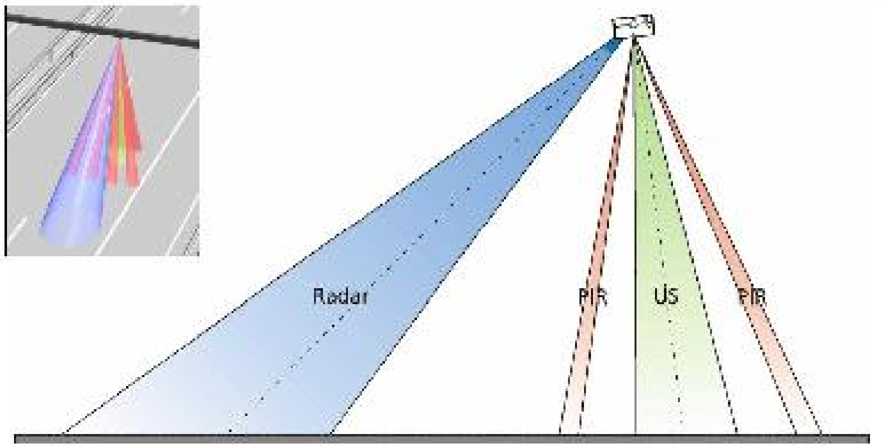
   Both systems could be integrated with other ITS solutions.

5. Tri-Tech TT 298 combination detector by Xtralis which is a triple technology detection solution using microwave doppler radar, ultrasonic and passive infrared. This unit will detect and classify vehicles by lane, and can cope with vehicles changing lanes, but is not appropriate in locations where stop/start conditions exist and where motorcyclists might lane-split (they will not be detected if travelling on the lane line). However located on the approach to an intersection, this application could be appropriate. A single unit is required for each lane on the approach to the intersection. Motorcycles changing lanes will be detected, but a motorcycle travelling exactly along the lane line at the point of detection will not be detected.

Figure 7: Tri-Tech Device

Figure 8: Tri-Tech Operation

Figure 9: Tri-Tech Operation



6. Camera / video imaging, such as that used on EastLink and CityLink for tolling purposes. This is an expensive solution, but is likely to be the most accurate for motorcycle detection and classification.

7. Ultrasonic vehicle detectors alone will not classify motorcycles from other vehicles.

8. Vehicle tags and roadside transmitters (not considered further within this study as these are in-vehicle technologies)

Warning Advice

Options for driver warning advice about an approaching motorcycle include:

- In-vehicle communications (not included within this study)
- Variable message sign (VMS) or vehicle activated sign (VAS) on the side of the road to provide:
  - Minor road warning
  - Major road warning
  - Right turn / oncoming traffic warning

These options are immediately applicable, and could be used in future vehicle to infrastructure solutions, and vehicle to vehicle solutions.

Control at Signalised Intersections

Additional options that would provide improved safety for motorcyclists but without providing warnings include the following additional controls at signalised intersections:

- Extended all-red phases at signalised intersections or extended red signal on one approach
- Fully controlled right turns
- Red light cameras

SUITABILITY OF SOLUTIONS FOR INTERSECTION TYPES

The suitability of the potential infrastructure and technology solutions for specific intersection types has been considered. Part One of this study investigated the crash history of motorcycle crashes occurring at intersections during the five-year period of 1 January 2003 to 31 December 2007. This highlighted the following most-common motorcycle crash scenarios:

- Cross traffic (DCA 110) at cross intersections
- Right through (DCA 121) at cross intersections
- Right near (DCA 113) at T-intersections
- Right through (DCA 121) at T-intersections
- The proportion of crashes at cross intersections was approximately the same for intersections with and without traffic signal control
- The proportion of crashes at T-intersections was significantly higher at unsignalised intersections than at signalised T-intersections (probably due to the provision of these across the network)

With regard to intersection control, traffic signal control accounted for 26% of all motorcycle intersection crashes, whilst unsignalised intersections accounted for 65%, and roundabout control 9% of crashes.

At intersections with traffic signal control, the most common crash type is right through (DCA 121). At roundabouts the most common crash type is cross traffic (DCA 110). At unsignalised intersections, the most common crash type is right near (DCA 113) and right through (DCA 121).

The crash scenarios investigated with regard to potential infrastructure or technology solutions to improve rider safety are summarised in Table 1.

Table 1: Infrastructure & Technology Solutions for Motorcycle Crash Types

Motorcycle Crash Type	Infrastructure & Technology Solutions
Right through crashes at traffic signal controlled cross intersections	a) Extend all red phase b) Extend red signal phase on one approach c) Fully control right turns d) Vehicle activated sign (VAS) or Variable message sign (VMS) warning to other drivers of approaching motorcycle
Right through crashes at traffic signal controlled T-intersections	a) Extend all red phase b) Extend red signal phase on one approach c) Fully control right turns d) VAS or VMS warning to other drivers of approaching motorcycle
Right through crashes at unsignalised T-intersections	a) Improve sightlines & reduce vehicle speeds (e.g. construct roundabout) b) VAS or VMS warning to other drivers of approaching motorcycle
Right near crashes at unsignalised T-intersections	a) Improve sightlines & reduce vehicle speeds (e.g. construct roundabout) b) VAS or VMS warning to other drivers of approaching motorcycle
Cross traffic crashes at unsignalised cross intersections	a) Improve sightlines & reduce vehicle speeds (e.g. construct roundabout) b) VAS or VMS warning to other drivers of approaching motorcycle
Cross traffic crashes at roundabouts	a) Improve sightlines & reduce vehicle speeds b) VAS or VMS warning to other drivers of approaching motorcycle

At intersections with traffic signal control, extension of the all red phase, extension of the red phase on one approach and fully controlled right turns will improve safety for all road users, and not just motorcycle riders. However there is likely to be a reduction in intersection performance during congested periods. Extension of red phases (on all or one approach) will assist to reduce the number of crashes that occur at the start of the red phase, but will not reduce the number of failed to give way violations during green phases. Detector loops would need to be installed within the intersection infront of the stop line to detect a vehicle waiting to turn right (i.e. beyond the stop line).

The physical location of a VAS or VMS will impact on the effectiveness of the sign to warn other drivers of approaching motorcyclists (i.e. the sign must be located within the line of vision of the driver who may be at a busy intersection trying to select a gap in oncoming traffic to undertake a right turn). Location of a VAS or VMS on the opposite side of a T-intersection to reduce the number of right near crashes might be able to be implemented consistently. Locating a sign on the approach or far-right corner of an intersection to assist reducing right through crashes may require more detailed case-by-case investigation for site suitability. The motorcycle detection and warning via VAS or VMS could be such that other drivers approaching the intersection receive the warning on the approach to the intersection, not just when they reach the intersection. They may therefore be more likely to realise and respond to the warning, than if the message is display with a lag when they are already at the intersection. This should be explored in more detail in trial applications.

SYSTEM REQUIREMENTS

The system requirements for the technology solutions are provided in Table 2. The devices typically require power, and communications to the vehicle activated or variable message sign. Some devices require additional system integration hardware and software to classify motorcycles in real time.

Table 2: Technology Solutions System Requirements

Option	Technology Solution	Device Components
1	Detector loops & chassis (Excel Technology Group)	- RS232 or RS422 serial ports - Ethernet
2	Radar and detector loops (A1 Roadlines)	- RS232 or RS422 serial ports - Ethernet
3	Infrared such as the TIRTL (CEOS)	- 2 no. RS232 serial ports - GPS unit - 3G mobile module optional - PSTN modem optional
4	Autosense laser scanner (OSI Laserscan)	- RS232 or RS422 serial ports - Fibre optic optional interface
5	Tri-Tech TT298 (radar, ultrasonic & infrared, by Xtralis)	- RS485 bus - RS232 optional interface
6	Camera / video imaging	- Ethernet - 3G mobile - PSTN modem

The units can typically be powered by a nearby point of supply (some require a transformer to provide a lower voltage to the unit itself), solar or battery.

INFLUENCE OF SOLUTIONS ON COMMON CRASH TYPES

The influence of the potential infrastructure and technology solutions on common crash types has been assessed. The estimated crash reduction factors from the possible technology solutions are shown in Table 3. These have been adopted from the VicRoads Road Safety Program spreadsheet where possible.

Table 3: Infrastructure & Technology Solutions for Motorcycle Crash Types

Motorcycle Crash Type	Infrastructure & Technology Solutions	Estimated Motorcycle Crash Reduction Factors
Right through crashes at traffic signal controlled cross intersections	a) Extend all red phase b) Extend red signal on one approach c) Fully control right turns d) Warning via VAS or VMS	30%[8] 30%[8] 55% 40%
Right through crashes at unsignalised T-intersections	a) Improve sightlines & reduce vehicle speeds b) Warning via VAS or VMS	30%[9] – 75%[10] 40%
Right near crashes at unsignalised T-intersections	a) Improve sightlines & reduce vehicle speeds (e.g. roundabout) b) Warning via VAS or VMS c) Install traffic signal control	30%[9] – 75%[10] 40% 45%
Cross traffic crashes at unsignalised cross intersections	a) Improve sightlines & reduce vehicle speeds (e.g. roundabout) b) Warning via VAS or VMS c) Install traffic signal control	30%[9] – 75%[10] 40% 45%
Cross traffic crashes at roundabouts	a) Improve sightlines & reduce vehicle speeds b) Warning via VAS or VMS	30%[9] 40%

[8] Estimated to be approximately half the benefits of a fully controlled right turn
[9] Improved sight distance (removal/relocation of obstruction) is estimated to have a CRF of 30%
[10] New roundabout has a CRF of 75% for motorcycle crashes

COST AND AVAILABILITY OF SOLUTIONS

The cost of the technology solutions is provided in Tables 4 - 7. The cost of infrastructure improvements such as construction of roundabouts or sightline improvements are site dependent and have therefore not been included in this report.

Table 4 shows the supply and installation costs of the vehicle detection and classification options, the system integration (if required), and the annual maintenance cost of the systems. Estimates are provided for initial trial sites, and on-going implementation sites which exclude the set-up costs that are required with some of the options as noted. The cost estimates provided are for vehicle detection and classification to be provided on one approach to an intersection.

Following tables show the communication costs and the costs of the warning provision and traffic signal remodel options.

Table 4: Costs for Motorcycle Detection & Classification, and System Integration

Option	Solution	Vehicle detection & classification (on one approach) Supply & Installation Cost ($)	System Integration Supply & Installation Cost ($)	Annual Maintenance Cost ($)	Trial Sites Total Supply & Installation Cost ($)	On-going Implementation Total Supply & Installation Cost ($)
1	Detector loops (2 per lane) & chassis (Excel Technology Group)	10,000 one lane 11,500 two lanes[11]	3,300[12]	280[13]	13,500 one lane 15,000 two lanes	7,000 one lane 8,000 two lanes
2	Radar vehicle wave detector plus detector loops (A1 Roadlines)	10,000 one lane 20,000 two lanes[14]	20,000[15]	550[16]	30,000	15,000 one lane[17] 25,000 two lanes
3	TIRTL infrared vehicle detectors (CEOS)	40,000[18]	0	325[19]	40,000	40,000
4	Autosense laser scanner (OSI Laserscan)	22,000 one lane 44,000 two lanes[20]	0	395[21]	22,000 one lane 44,000 two lanes	22,000 one lane 44,000 two lanes
5	TT 298 Tri-tech combination (Xtralis)	18,000 one lane 36,000 two lanes[22]	1,500[23]	1,050[24]	19,500 one lane 37,500 two lanes	19,500 one lane 37,500 two lanes
6	Image processing vehicle detectors (EastLink & CityLink)	>100,000		10,000[25]	>100,000	>100,000

[11] 2 detector loops per lane @ $650 each loop, plus $8,680 for first device, or $5,500 per unit for three devices, costs rounded
[12] Software development for first device only (following installations have no cost)
[13] 1 inspection p.a. (cleaning detector surface & checking data collection, $250), warranty 1 yr, 10 yr life, assume one replacement part during life $300 (ave over 10 yrs = $30p.a.)
[14] Radar detector $8,600 plus 2 detector loops per lane @ $650 per loop
[15] Estimate – hardware required and development of the appropriate software, which does not exist at this stage
[16] 2 inspections p.a. (cleaning detector surface & checking data collection, $500), warranty 1 yr, 6+ yr life, allow $50p.a. to replace batteries & padlocks on unit if vandalised
[17] $5,000 allowed for system integration hardware (unknown)
[18] $35,000 for TIRTL pair and $5,000 estimated for installation (kerb & channel, base for TIRTL units, pavement), up to 9 traffic lanes can be monitored by one TIRTL pair
[19] 1 inspection p.a. (cleaning detector surface & checking data collection, $250), warranty 1 yr, 20+ yr life, only units to have required upgrades were struck by lightning or vandalised, replacement unit cost = $750 (ave over 10 yrs = $75p.a.)
[20] $10,000 per unit plus $12,000 assumed for pole installation (similar to JUP / MA), 2 lanes require 2 units and 2 poles
[21] 1 inspection p.a. (cleaning detector surface & checking data collection, $250), warranty 1 yr, 10yr life, replacement parts typically $1,450 (ave over 10 yrs = $145p.a.)
[22] $6,000 per unit plus $12,000 assumed for pole installation (similar to JUP / MA), 2 lanes require 2 units and 2 poles
[23] PC required for vehicle classification
[24] 1 inspection p.a. (cleaning detector surface & checking data collection, $250), warranty 2 yrs, 5-7yr life, replacement unit = $4,000 (ave over 5 yr life = $800p.a.)
[25] Assumed annual cost, information difficult to obtain

Table 5 shows the costs to provide communication between the vehicle detection and classification device and the vehicle activated sign (VAS) or variable message sign (VMS).

Table 5: Communication

Solution	Supply & Installation Cost ($)	Annual Maintenance Cost ($)
Hard wired	58,400[26]	400
Radio	5,000[27]	100[28]
3G communication	100[29]	1,200 ($10 per month access)

Table 6 shows the costs of the warning provision for other drivers and traffic signal remodel options.

Table 6: Warning Provision & Traffic Signal Remodel

Solution	Supply & Installation Cost ($)	Annual Maintenance Cost ($)
Variable message sign	50,000	1,000
Vehicle activated sign (one message, on or off)	35,000	1,000
Fully controlled right turn (signal and remodel costs only, civil works may be required to extend right turn lanes)	15,000[30]	n/a
Extended all red time (signal remodel only)	5,000	n/a
Extended red signal time on one approach (signal remodel & installation of detection loops in advance of stop lines on all approaches)	7,600[31]	n/a

Therefore the combined cost for a trial to detect motorcycles on <u>one</u> approach and warn drivers on a <u>single</u> approach at an intersection would be at least as follows (the cheapest alternative is shown):

> $13,500 (detector loops, one lane approach)
> $ 700 (3G communication for 6 month trial)
> <u>$35,000</u> (VAS)
> <u>$49,200</u>

[26] Conduit $350/m conduit (bored) or $250/m conduit (open trench), $1,600 / pit, cable $25/m, point of supply on existing pole $1,400. Assume 200m conduit (open trench) and cable, single pit and point of supply. In addition, pair of converters for serial output $400.

[27] When used with detector loops, allow additional $3,000 for pole (similar to 2B pedestal) to mount radio antenna

[28] Estimated, new technology being used

[29] Estimate, no charge with account of multiple sim cards

[30] Includes $5,000 signal remodel costs plus $1,500 per 6 aspect signal lantern and $1,000 per 3 aspect signal lantern (allowing for 4 no. 6 aspect lanterns and 4 no. 3 aspect lanterns)

[31] Includes $5,000 signal remodel costs plus 4 detector loops @ $650 per loop

The combined cost to detect motorcycles on all approaches and warn drivers on all approaches to a cross intersection would be at least as follows (the cheapest alternative is shown):

$ 54,000 (detector loops on 4 approaches, one lane approaches)
$ 700 (3G communication for 6 month trial)
$140,000 (VAS on 4 approaches)
$194,700

The cost of a trial on all four approaches to a cross intersection would therefore cost nearly $200,000.

RECOMMENDATIONS

Motorcycle Crash Scenarios

It is recommended that a number of trials be conducted to review the accuracy of the vehicle classification technology available, and the impact on motorcycle crashes, as shown in Table 7. Due to the dispersal of motorcycle intersection crashes across the urban road network, it would be difficult to install technology solutions at each intersection. A small number of intersections with a high number of motorcycle crashes could be trialled.

At intersections with a history of motorcycle crashes, it may be more cost effective to address geometric, sightline and roadside hazard constraints prior to implementing technology solutions.

Table 7: Options for Technology Solutions

Scenario	Motorcycle Crash Type	Options for Technology Solutions
1	Right through crashes at traffic signal controlled cross intersections	a) Motorcycle detection & classification on approach to intersection & warning provided via VAS b) Fully control right turns c) Extend all red phase d) Extend red phase on single approach when vehicle detected waiting to turn right
2	Right through crashes at traffic signal controlled T-intersections	a) Motorcycle detection & classification on approach to intersection & warning provided via VAS b) Fully control right turns c) Extend all red phase d) Extend red phase on single approach when vehicle detected waiting to turn right
3	Right through crashes at unsignalised T-intersections	a) Motorcycle detection & classification on approach to intersection & warning provided via VAS
4	Right near crashes at unsignalised T-intersections	a) Motorcycle detection & classification on approach to intersection & warning provided via VAS
5	Cross traffic crashes at unsignalised cross intersections	a) Motorcycle detection & classification on approach to intersection & warning provided via VAS
6	Cross traffic crashes at roundabouts	a) Motorcycle detection & classification on approach to intersection & warning provided via VAS

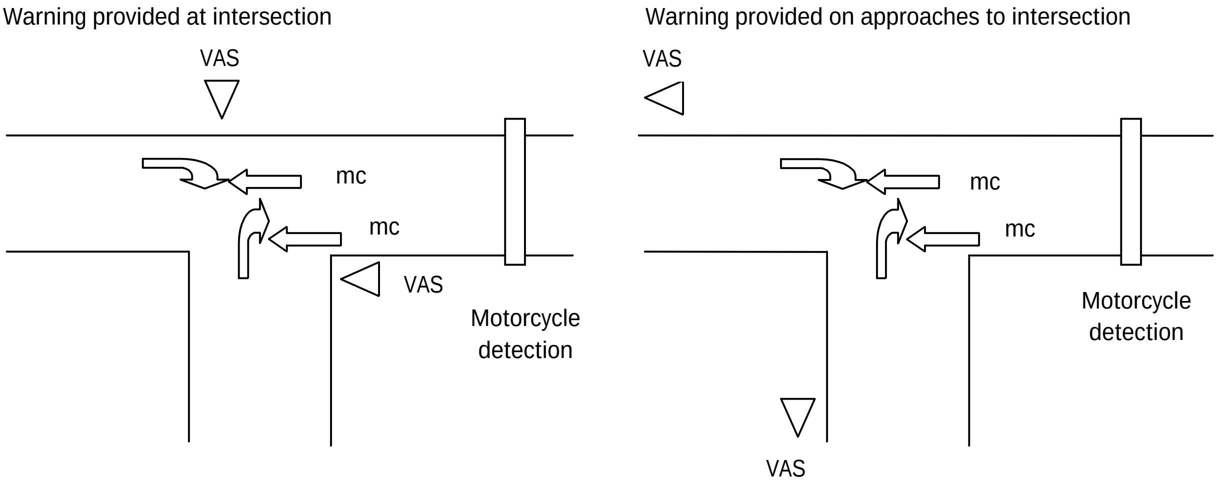
The most cost-effective trials would be in scenarios 2 - 4, where in each case one approach to an intersection can be used for the motorcycle detection and classification, and one VAS or VMS could be used to warn other motorists of approaching motorcyclists. An indicative cost for a two lane major road with detector loops, 3G mobile communication and one vehicle activated sign is $50,700 (6 month trial). A similar trial using the TT 298 Tri-tech device, 3G mobile communication and one vehicle activated sign would cost $73,200.

This could be combined into one site, where motorcycles are detected on one approach, and warnings provided on the opposite approach for right turning drivers, and the minor approach (refer to Figure 10). An indicative cost for a two lane major road with detector loops, 3G mobile communication and two vehicle activated signs is $85,700 (6 month trial). A similar trial using the TT 298 Tri-tech device, 3G mobile communication and two vehicle activated signs would cost $108,200.

Trials at cross intersections would require the provision of motorcycle detection and warnings to be provided on all four approaches, unless there was a history of motorcycle crashes on one approach only. An indicative cost for a two lane major road with detector loops, 3G mobile communication and four vehicle activated signs is $197,400 (6 month trial).

To trial options for scenario 1, it is suggested that options (b), (c) and (d) are investigated. It is understood that a separate study is currently underway for VicRoads into the provision of fully controlled right turns at intersections. Option (a) could be trialled if one approach of an intersection shows a history of motorcycle crashes.

Figure 10: Representation of Motorcycle Detection & Warning at Unsignalised T-intersection



Trial Sites

Review of the crash data investigated in Part One of this study shows that there are a number of sites where more than one right through (DCA 121) or right near (DCA 113) motorcycle crashes occurred during the five-year study period. However there are no sites that had two or more of each type of crash. Table 8 shows a number of sites where the trials could be implemented.

Table 8: T-Intersections with Two or More Right Through (DCA 121) or Right Near (DCA 113) Crashes involving Motorcycles (1/01/2003 – 31/12/2007)

Location	LGA Name	Map Ref	DCA	Number of Motorcycle Crashes
Inkerman Street / Greeves Street	Port Phillip	2P D7	121	2
Princes Highway East / Olive Road	Casey	91 A12	121	2
Reynolds Road / Tindals Road	Manningham	35 A7	121	2
Springvale Road / Station Street (will be affected by the Springvale Road grade separation of the railway line and is therefore not an appropriate trial site)	Whitehorse	48 F10	121	2
Melbourne-Lancefield Road / Sunbury Road	Hume	383 A9	113	2
Cotham Road / Thomas Street	Boroondara	45 G7	113	2
McGregor Road / Main Street (adjacent to Princes Highway East)	Cardinia	317 C7	113	2
Princes Highway East / Garden Road	Dandenong	79 J3	113	2
Frankston – Dandenong Road / Highland Drive	Frankston	106 H1	113	2
Beach Road / Warrigal Road	Kingston	87 B9	113	2
Wellington Road / Viewtech Place	Knox	81 F3	113	2
Liverpool Road / Glasgow Road (Council is seeking funding for traffic signals at the intersection under the Federal Blackspot program)	Yarra Ranges	51 H12	113	2
Springvale Road / Laughlin Avenue (will be affected by the Springvale Road grade separation of the railway line and is therefore not an appropriate trial site)	Whitehorse	48 F10	113	2

Estimated BCRs range from less than 1.0 (where two other injury crashes occurred in a 60km/h speed zone) to 14.11 (where a fatal and serious injury crash occurred in a 70km/h zone or a fatal and other injury crash occurred in an 80km/h zone) for sites with two motorcycle crashes. A site with a crash history of one serious injury and one other injury crash, in a 60km/h zone, still yields a BCR of 6.16 for $50,000 cost (detector loops, one VAS and radio communication). The estimated BCR is dependent on the cost of the solution, the number and severity of motorcycle crashes at the site, and the speed zone.

POSSIBLE FURTHER STUDY

Further research could include a study of near miss crashes at an intersection with a high number of motorcycle crashes, to allow review of why the crashes occur. A similar study in Europe allowed authorities to understand the causation of crashes at a specific intersection, and therefore modify the layout of the intersection, which significantly reduced incidents (advice from the Federation of European Motorcyclists Association, FEMA).

ATTACHMENT A – PRODUCT DATA SHEETS

SDR RADAR

<table>
<tr><th colspan="4">SDR RADAR CLASSIFIER</th></tr>
<tr><th></th><th>Description</th><th>Price Each
Ex GST</th><th>Price Each
Inc GST</th></tr>
<tr>
<td>

</td>
<td>The SDR Radar Classifier is a fully self contained, non-intrusive traffic measuring device. The SDR measures and stores all passing vehicles in 2 directions with their :-

▪ Speed
▪ Time
▪ Date
▪ Direction of travel
▪ Vehicle length

<u>Features</u>

▪ Lightweight lockable & weather proof portable case
▪ Can be powered by internal battery (Optional Extra) or connected to existing traffic calming device – i.e VSD trailer, Arrow Trailer, etc
▪ One person able to easily set up and operate
▪ Mounts at 45 degree angle for accurate classification and counting of all vehicles passing in two directions.
▪ Data easily outputs to excel format
▪ Unit comes with its own PDA (Palm) for data collection
▪ All data conveniently downloads to a palm PDA allowing for simple and convenient transfer between radar unit and your PC.

<u>Applications</u>

School Zones, Residential Neighbourhoods, Pedestrian Black Spots, Construction or Work Zones

<u>Modes of Operation</u>

The SDR can be set up for single lane or 2 lane use (bi-directional)
<u>Speed Range</u>
Standard memory measures up to 57,000 vehicles. Memory can be extended to store 1,600,000 vehicles.

Technical Details:
Speed Range: 3 – 250 km
Weight: 4.7 kg
Dimensions: 300 x 350 x 150mm
Memory: 128 MB
Calibration: Automatic or Manual</td>
<td>$ 7,500.00
SDR & PDA</td>
<td>$ 8,250.00
SDR & PDA</td>
</tr>
<tr>
<td rowspan="2">Optional Extra’s</td>
<td>Internal Battery Kit (P/N SDR-0001)

▪ 12V 10 AH Batteries (2)
▪ Battery Charger (1)</td>
<td>$ 175.00</td>
<td>$ 192.50</td>
</tr>
<tr>
<td>Pole Mounting Bracket Kit (P/N SDR-0002)

▪ Includes 60mm, 76mm, 90mm, 102mm & 114mm OD</td>
<td>$ 90.00</td>
<td>$ 99.00</td>
</tr>
</table>

TIRTL INFRARED

11. Specifications

11.1. Technical Specification

Description	Specification
TIRTL Version	2.0
Speed measurement accuracy	±1% (30 - 250km/hr, 20 – 155mph)
Maximum number left bound lanes	9
Maximum number right bound lanes	9
Max. Tx/Rx separation distance	100m / 330ft
Max Tx/Rx separation (long range optic)	200m / 660ft
Operating temperature range	-40 to +85ºC / -40 to 175ºF
Environmental waterproof rating	IP67 (Main body)
	IP65 (Battery compartment)
EMI Rating	AUNZS 55022:2000 Class B
Safety Approval	AUNZS 60950:2002 compliant
DC Input Voltage	10-16 V DC
Average Rx Power Consumption at 25°C	800 mW (no traffic)
	1000 mW (dense traffic)
Peak Rx Power Consumption at 25°C	2500 mW
Average Tx Power Consumption at 25°C	640 mW
Processor	x486, 33 MHz
Operating System	Linux (kernel 2.2)
On Board RAM	16MB
On Board ROM	8MB - 64MB
Compact Flash Storage (log storage):	1,024MB (~ 100,000 – 7M vehicles)
Communication Interfaces	2 x RS232 serial ports
	GPS unit
Optional modules	3G mobile module
	PSTN modem

Table 6 – Technical specification

AUTOSENSE LASER SCAN

AutoSense 600, 700 & 800 Series Specifications

Performance	AS 615	AS625	AS 705	AS 715	AS 815
Use	Single Lane—Open Road or Toll Barrier to achieve vehicle detection, separation, classification and camera trigger	Single Lane—Open Road to achieve Truck/Lorry detection, separation, classification, physical parameters determination, camera trigger	Open Road/Free Flow—Vehicle detection, separation axle classification and camera trigger	Toll Plaza/Barrier Lane—Vehicle detection, separation axle classification and camera trigger	Two Lane, Open Road/Free Flow applications to achieve vehicle detection, separation, classification and camera trigger
Mounting Location	Overhead: 5.9m – 7.6m 19.5 Ft – 25 Ft	Overhead: 7.6m – 9.2m 25 Ft – 30Ft	Side Fire: mounting height determined by sensors setback from travel lane.	Side Fire: mounting height determined by sensors setback from travel lane	Overhead: 7.6m – 9.2m 25 Ft – 30Ft
Field of View	30 degrees	30 degrees	30 degrees	40 degrees	60 degrees
Laser Pixel Density	.5 degree to 1 degree configurable across full FOV, both beams	.5 degree to 1 degree configurable across full FOV, both beams	.5 degree to 2 degrees configurable across full FOV, both beams	.5 degree to 2 degrees configurable across full FOV, both beams	.67 degree across full FOV, both beams
Vehicle Classification Categories	11 Standard Categories, plus 20 User-definable categories	User Definable	Axle Count	Axle Count	11 Standard Categories, plus 20 User-definable categories
Vehicle Detection Accuracy	>99.9% (one vehicle in field-of-view)	>99.9% (one vehicle in field-of-view)	>99.9% (one vehicle in field-of-view)	>99.9% (one vehicle in field-of-view)	>99.9% (two vehicles in field-of-view)
Vehicle Classification Accuracy	>95% (into 6 vehicle classes)	>95% (into 6 vehicle classes)	>99%	>99%	>95% (into 6 vehicle classes)
Vehicle Speed Accuracy	± 10%	± 10%	± 10%	± 10%	± 10%
Vehicle Height Accuracy	± 3 inches (± 76 mm)	± 3 inches (± 76 mm)	N/A	N/A	± 3 inches (± 76 mm)
End-of-Vehicle Detection Signal	~1 foot (0.3 M) after vehicle exits 2nd beam	~1 foot (0.3 M) after vehicle exits 2nd beam	~1 foot (0.3 M) after vehicle exits 2nd beam	~1 foot (0.3 M) after vehicle exits 2nd beam	~1 foot (0.3 M) after vehicle exits 2nd beam
Vehicle Spacing Resolution	10 feet at 125 mph (3 m at 200 kph); 4 feet at 62 mph (1.2 m at 100 kph); 1.5 foot at 10 mph (.35m @ 18.2 kph)				
Side-by-Side Vehicle Spacing	3 degrees minimum between vehicles	N/A	N/A	N/A	3 degrees minimum between vehicles
Trailer Tow Bar Detection	>2 inches wide, >2 feet long up to 125 mph (>5 cm wide, >60 cm long up to 200 kph)	>2 inches wide, >2 feet long up to 125 mph (>5 cm wide, >60 cm long up to 200 kph)	>2 inches high, >2 feet long up to 125 mph (>5 cm high, >60 cm long up to 200 kph)	>2 inches high, >2 feet long up to 125 mph (>5 cm high, >60 cm long up to 200 kph)	>2 inches wide, >2 feet long up to 125 mph (>5 cm wide, >60 cm long up to 200 kph)
Physical					
Power Input	200-264 V, 50-60 Hz, 1.0 A or 90-140 V, 50-60 Hz, 1.5 A	200-264 V, 50-60 Hz, 1.0 A or 90-140 V, 50-60 Hz, 1.5 A	200-264 V, 50-60 Hz, 1.0 A or 90-140 V, 50-60 Hz, 1.5 A	200-264 V, 50-60 Hz, 1.0 A or 90-140 V, 50-60 Hz, 1.5 A	200-264 V, 50-60 Hz, 1.0 A or 90-140 V, 50-60 Hz, 1.5 A
Power Consumption	35 watts nominal, 157 watts maximum	35 watts nominal, 157 watts maximum	35 watts nominal, 157 watts maximum	35 watts nominal, 157 watts maximum	40 watts nominal, 160 watts maximum
Dimensions	17.9 x 9.6 x 6.1 inches (Length x Width x Height) (455 x 244 x 155 mm)	17.9 x 9.6 x 6.1 inches (Length x Width x Height) (455 x 244 x 155 mm)	17.9 x 9.6 x 6.1 inches (Length x Width x Height) (455 x 244 x 155 mm)	17.9 x 9.6 x 6.1 inches (Length x Width x Height) (455 x 244 x 155 mm)	16 x 13.5 x 5 inches (Length x Width x Height) (406x 343x 127 mm)
Weight	20.5 pounds (9.3 Kg)	20.5 pounds (9.3 Kg)	20.5 pounds (9.3 Kg)	20.5 pounds (9.3 Kg)	29.0 pounds (13.1kg)
Processor					
Onboard Computer Type	AD (Sharc) 21061, 32 bit, 40 MHz, DSP 120 MFLOPS with 50 MIPS	AD (Sharc) 21060, 32 bit, 40 MHz, DSP 120 MFLOPS with 50 MIPS	AD (Sharc) 21060, 32 bit, 40 MHz, DSP 120 MFLOPS with 50 MIPS	AD (Sharc) 21060, 32 bit, 40 MHz, DSP 120 MFLOPS with 50 MIPS	AD (Sharc) 21060, 32 bit, 40 MHz, DSP 120 MFLOPS with 50 MIPS
Multipulse Logic	4 Separate channel receivers to process up to 4 return signals from each laser pulse/pixel				
Data Interface					
Standard: RS-422 or RS-232 Serial	19.2, 38.4, 57.6 Kbaud (User selectable) 8 data bits, 1 start, 1 stop, no parity				
Optional: Fiber Optic Interface	850nm Optical Transceiver, 2 fiber, multiplex (high speed data, message data, logic data) up to 10 MB/s				
Environmental					
Temperature	-40 to +160 degrees F (with sun loading)				
Thermal Shock	60 degrees F/minute, 15.5 degrees C/minute				
Humidity	0 to 100% condensing				
Rain	0.8 inches/hour (20 mm/hour) operating 4 inches/hour (100 mm/hour) maximum				
Snow Loading	20 lb./ft^2 (98 Kg/m^2)				
Wind Loading	43 knots steady, 73 knots gusts				
Reliability	>35,000 hours (Mean Time Between Failures)				
Maintainability	15 minutes (Mean Time To Replace)				

U.S. Patents – 5,321,490/5,546,188/5,896,190 /5,575,472
International Patents Pending.

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sales@osi-ls.com

AutoSense™

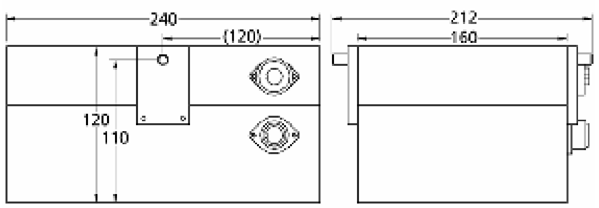
TRI-TECH TT298

10 Specification TT 290 Series

Mechanical	
Dimensions	see section 10.1
Enclosure	Polycarbonate, light-grey
Mounting Points	M8, stainless steel V4A
Weight	app. 1’800 g (3.95 lbs)
Microwave	
Doppler Radar	K-Band 24.05 … 24.25 GHz
FCC Identifier	R2DTT29X-453
Ultrasound	
Frequency	50 kHz
Pulse Frequency	10 … 30 Hz
Infrared	
Sensors	Multi channel dynamic curtains
Spectral Response	8 … 14 µm
Electrical	
Supply Voltage	10.5 … 30 V DC
Power Consumption	max. 110 mA @ 12 V DC typ. 25 mA in Standby (power save mode TT 293, refer to 7.1)
Output (Data Transfer)	RS 485 Bus. 9600, 8, e, 1
Turn-on Time	typ. 20 s from power on
Accuracy	
Counting	typ. ± 3%
Speed	typ. ± 3% (> 100 km/h) typ. ± 3 km/h (≤ 100 km/h)
Classification	Depending on model, refer to chapter 2.4. The specifications refer to free traffic flow, detector mounted above the centre of the lane to be observed and operated in Frontfire mode. Accuracy tends to be lower in other configurations and traffic conditions including, but not limited to Stop&Go traffic.
Environmental	
Operating Temperature	–40°C … +70°C (–40°F … +158°F)
Humidity	95 % RH max.
Sealing	IP 64 splash proof The detectors are not designed to be cleaned with water jets, e.g. tunnel cleaning! For such cases the detector must be dismounted or covered.

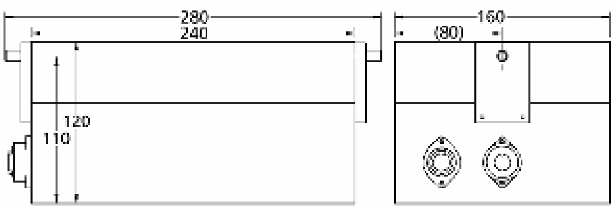
10.1 Mechanical Dimensions

Longitudinal



Dimensions in mm

Perpendicular



Dimensions in mm