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ANNUAL SUMMARY REPORT

Project Title: R46: Review and Analysis of Intersection Crashes on Queensland Roads

(Year 1 – 2015/16)

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Author/s: Michael Luy, Samantha Taylor, John Dickson and Dr Joseph Affum

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SUMMARY

Intersection crashes are one of the main severe crash types on Queensland roads. Queensland Department of Transport and Main Roads (the Department) is committed to the Safe Systems approach to road safety with the aim of reducing the number and severity of road crashes. In order to focus its safety activities in the right areas the Department commissioned ARRB Group to determine the contributing factors and key drivers behind this crash type. This will enable more specific and focused strategies to be adopted for improved safety outcomes.

The study involved a literature review and analysis of latest available crash data at intersections on Queensland roads over a five-year period from 2007 to 2011. The key findings include the following:

- Intersection crashes accounted for 44% of all injury crashes and 40% of fatal and serious injury (FSI) crashes on Queensland roads during the five-year period.
- On state-controlled roads, intersection crashes accounted for 40% of all injury crashes and 36% of FSI crashes, even though intersections accounted for less than 5% of the network.
- There was an overall reduction of 15% in intersection injury crashes over the five years (2007–11).
- The top five contributing factors recorded for intersection injury crashes were disobeying road rules, young adult drivers (16 to 24 years old), senior adult drivers (60 and above), controller condition and alcohol.
- Most of the intersection injury crashes occurred at T-junctions (47%), cross-intersections (34%) and roundabouts (10%); the three most common intersection types.
- The majority of intersection injury crashes occurred at intersections with no traffic control (33%), intersections with traffic lights (31%) and give way signs (27%).
- The major intersection injury crashes were angle crashes (57%), rear-end (21%), hit object (10%) and pedestrian crashes (4%), hence intersection programs should focus on treatments that address these crash types.
- DCA code 202 crashes accounted for 25% of intersection FSI crashes on state roads and 19% on locally controlled roads.
- About 61% of DCA code 202 crashes that resulted in FSI occurred at intersections with traffic lights.
- About 41% of FSI and 37% of all injury crashes that occurred at intersections controlled by traffic signals were DCA code 202 crashes.
- About 86% of intersection angle injury crashes occurred at T-junctions (43%) and cross-intersections (43%).
- The majority of rear-end intersection injury crashes occurred at intersections with no traffic control (39%), intersections with traffic lights (33%) and give way signs (27%).
- Most of the rear-end intersection injury crashes occurred at T-junctions (55%), cross-intersections (24%) and roundabouts (10%).

- Most of the pedestrian injury crashes at intersections occurred at T-junctions (49%) and cross-intersections (44%), especially those controlled by traffic lights. More than half (52%) of pedestrian injury crashes at intersections occurred at intersections controlled by traffic lights.
- The majority of hit object intersection injury crashes occurred at T-junctions (52%), followed by roundabouts (19%) and cross-intersections (16%).
- Most of the intersection injury crashes involving parked vehicles occurred at T-junctions (73%).
- Railway crossings had the highest FSI rate (52%) and highest fatality rate (9%), followed by multiple road intersections (42% FSI).
- Railway crossings controlled by sign only had the highest FSI rate (63%), followed by railway crossings controlled by flashing lights (53%).
- There were more intersection injury crashes (89%) on low speed roads (below 80 km/h) than all other injury crashes (73%).
- Middle-aged controllers (25 to 59 years old) made up the largest proportion of primary vehicle controllers involved in intersection injury crashes (60%), partly because they represent the widest range.
- Disobeying road rules was a factor in a high proportion of intersection injury crashes (79%), more than for all other injury crashes (67%).
- Crashes at unlit intersections were more severe than in other lighting conditions – unlit intersections recorded the highest proportion of FSI and fatal night-time crashes.
- Give way signs (27%), no traffic control (33%), traffic lights (31%), and stop signs (8%) were attributed to the most intersection injury crashes.
- As the primary vehicle controller, male drivers were involved in 59% of intersection injury crashes.
- The risk of an FSI intersection crash was highest for motorcycle/moped (55%), heavy vehicles (40%) and cyclists (40%).

Recommended engineering treatments to reduce the incidence of and/or severity of intersection crashes considering the crash findings have been provided in the recommendation section.

Further study is recommended to investigate and identify the safety implications of site-specific characteristics. The scope of the study should include identifying and investigating the site characteristics of intersections with higher than average and lower than average crash rates. The results from the investigation would help identify design and operational characteristics that influence road safety and to develop relationship between road features and crashes.

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1 INTRODUCTION

1.1 Background

A review of crash data has identified three key crash types occuring on Queensland roads, namely intersection crashes, run-off-road crashes and head-on crashes (Queensland Department of Transport and Main Roads 2013). These crash types accounted for 74% of serious injury crashes (fatal and hospitalised). To reduce the number and severity of crashes a focus on these crash types would provide the maximum benefits. To enable Qeensland Department of Transport and Main Roads (the Department) to focus its activities in the right areas, the key contributing factors to these crash types need to be understood, and the numerous variables attributed to these crashes identified. This understanding will enable more specific and focused strategies to be adopted for improved safety outcomes.

This project deals with a review and analysis of intersection crashes on Queensland roads.

1.2 Objectives

The objectives of the study are to:

- gain a greater understanding of road safety engineering based measures used to address serious injury crashes so that the most effective treatments can be used in future projects
- save life and prevent serious injuries
- improve effectiveness of road safety engineering countermeasures
- improve economic returns on investments from existing programs such as Safer Roads Sooner.

1.3 Methodology

The following tasks were undertaken as part of the project:

- review and evaluation of existing strategies to address intersection crashes and determine their usefulness in reducing serious intersection crashes
- a comprehensive analysis of all intersection crashes on the Queensland road network, including both local and state roads
- identification of potential new engineering treatments that may reduce intersection crashes
- review of current funding program structures to identify potential improvements and determine new strategies to be adopted to reduce the number and severity of serious intersection crashes.

2 LITERATURE REVIEW

A literature review and internet search was undertaken to identify and evaluate strategies that address intersection crashes and determine their usefulness in reducing serious crashes.

The literature review utilised ARRB's MG Lay Library, which is the leading transport library in Australia. Searches included the Australia Transport Index, Transport and Transportation Research Information Services (TRIS) databases whose contents are coordinated by ARRB Group, the Organisation for Economic Co-operation and Development (OECD) and the U.S. Transportation Research Board respectively.

2.1 Background Research

There has been significant national and international research in recent years regarding intersection crashes. This includes Austroads research undertaken to feed into future updates of the Austroads Guides.

The results of this Austroads research are particularly relevant to this study and provide a significant input into the literature review. These have been supplemented by published papers and internet search results. The key Austroads reports include:

- Road Safety Engineering Risk Assessment Part 9: Rural Intersection Crashes (2010a)
- Safe Intersection Approach Treatments and Safer Speeds Through Intersections: Final Report, Phase 1 (2010b)
- Safe Intersection Approach Treatments and Safer Speeds Through Intersections: Phase 2 (2011)
- Effectiveness of Road Safety Engineering Treatments (2012)
- Improving the Performance of Safe System Infrastructure: Final Report (2015b).
- Guide to Road Safety Part 8: Treatment of Crash Locations (2015d)

2.2 Intersection Crash Contributory Factors

Various elements of the road and road environment, along with human behavioural factors, have the potential to contribute to the likelihood and severity of crashes. Common intersection crash contributory factors include (Austroads 2008, 2010a, 2015a, 2015d; Corben et al. 2005):

- road and road environment factors including:
  - restricted sight distance caused by downhill bends, sharp horizontal curves, etc.
  - inappropriate speed limits
  - inappropriate intersection control and signage
  - inadequate street lighting
  - poorly maintained and/or insufficient pavement markings
  - unclear vehicle path through intersection
  - unsealed or poorly maintained road shoulders
  - poor and/or inappropriate delineation and alignment
  - road pavement poorly maintained or too narrow
  - roadside hazards such as trees, culverts, etc.
  - poorly designed freeway interchange ramps

  - presence of land development adjacent to the road

- human behavioural factors including:
  - failure to give way
  - failure to perceive the presence of an intersection
  - failure to change lanes correctly
  - failure to signal or signalling incorrectly
  - failure to detect and/or comprehend traffic control device
  - failure to check sight lines obscured by lead vehicle
  - failure to maintain an appropriate following distance (i.e. tailgating)
  - failure to detect traffic and pedestrians
  - failure to anticipate actions or intentions of other drivers and pedestrians
  - failure to estimate velocity, distance or gap between other vehicles
  - failure to consider all factors when accepting gaps
  - failure to clear an intersection
  - inappropriate approach speed
  - failure to plan journey (i.e. way-finding).

2.3 Intersection Crash Treatments and their Effectiveness

Current best practices of road planning and design aim to reduce the likelihood and severity of serious injuries when crashes occur by providing road users with a ‘forgiving’ road system. In time, however, population growth, vegetation growth and urban development followed by increased traffic flow may lead to intersections in the road network becoming crash prone and in need of engineering treatments to reduce crash risk.

The extent, type and effectiveness of intersection crash treatments required depend on many factors including the configuration and location of the intersection being treated and the funds available. For example, a study conducted by Candappa et al. (2006) found that treatments that prove effective in rural areas may not necessarily be as effective in urban areas. This is likely due to intersection crash types in urban areas being more diverse, whereas rural areas with simpler intersections will likely have a dominant crash type, which can be targeted by a single treatment.

Almost all well-known intersection crash treatments are infrastructure based and do not rely on any vehicle-mounted devices. In order to combat human behavioural contributory factors (e.g. inattention), vehicle-mounted devices such as automated braking systems and collision warning systems are available in some new vehicles. However, as crashes are infrequent events and extensive data is required to evaluate the effectiveness of crash treatments, more research into their effectiveness is required. A review of existing knowledge regarding vehicle-mounted intersection crash treatments can be found in Section 2.3.8.

Significant national and international research into intersection crash treatments and their effectiveness has been carried out, with many road agencies developing guidelines for their design and implementation. The following sections summarise the types of treatments used and their effectiveness based on their crash reduction potential.

2.3.1 Traffic Control and Operational Treatments

Traffic control and operational treatments involve adding, removing or manipulating traffic signal phases with the aim of reducing intersection crashes including rear-end, right-angle, head-on or right-through crashes. Commonly adopted traffic control treatments include:

- installation of traffic signals
- provision of dedicated left-turn and/or right-turn traffic signal phases
- optimisation of intersection clearance intervals
- improved provision for pedestrians and bicycles at intersections
- restriction of or permission for particular turning manoeuvres including left turn on red.

Intersection signalisation

The installation of traffic signals is a means of restricting conflicting flows of traffic and hence can reduce intersection crashes, particularly right angle crashes. It can also improve pedestrian and cyclist safety. Austroads (2012) and iRAP (2010) indicate a 30% and 25 - 40% crash reduction respectively, for the installation of traffic signals.

Dedicated left-turn and right-turn traffic signal phases and longer phase intervals

The provision of dedicated left-turn and/or right-turn traffic signal phases can reduce the frequency of rear-end crashes, right-through crashes and right angle crashes. At intersections without dedicated right-turn phases, drivers are required to screen/filter oncoming through traffic and then make a right-turn movement across the oncoming lane when they think it is safe to do so (Chen & Meuleners 2013). Should a driver err in determining a safe gap, this may lead to a right-through collision which, in a high-speed environment, is potentially very serious.

Chen and Meuleners (2013) investigated the effects of dedicated right-turn phases at signalised intersections and found a significant decrease in serious injury crashes:

- 24% decrease in all reported crashes
- 69% decrease in right angle/right-through crashes
- 10% decrease in rear-end crashes
- 58% decrease in serious injury crashes.

Austroads (2012) reported the following crash reductions:

- 35% for all casualty crashes
- 60% for right-through crashes
- 45% for adjacent direction crashes
- 70% when changing from partial to fully controlled right turns.

The Arizona Department of Transportation (2009) reported the following crash reductions

- 15% decrease in all crashes
- 35% decrease in all right-turn crashes.

Baldock et al. (2005) noted that supplementing new or existing dedicated right-turn phases with longer phase intervals may lead to a decrease in the frequency of rear-end crashes as this provides for more vehicles to cross an intersection, which in turn discourages drivers from careless driving.

Optimisation of clearance intervals (i.e. all-red phases) has been proven to be effective in reducing intersection crashes (NCHRP 2004). This crash treatment is most effective at intersections where there is a high frequency of crashes related to phase change lengths that are possibly too short, e.g. rear-end crashes resulting from a need for the leading driver to stop abruptly and the following driver not having enough time to react accordingly. This crash treatment has also proven to be a low-cost option with minimal implementation time required However, care must be taken to ensure that yellow phases are not so short that abrupt stopping results in an increase in rear-end crashes and red phases are not so long that red light running becomes common.

Left turn on red

Left turn on red (LTOR) is an operational measure that has not been widely deployed in Australia; however, extensive research on the treatment has been carried out internationally since as early as 1956 (Fleck & Yee 2002; Wagoner 1992; Lord 2002; Love & True 1976; Ray 1956). It has been found that LTOR has the potential to decrease the number of rear-end crashes; however, at cross-intersections, LTOR increases the potential for the following four types of conflicts (Qi, Chen & Li 2012):

- cross-street through movement
- opposing left-turn movement
- cross-street U-turns
- cross-street pedestrians.

However, a survey carried out by Lord (2002), found that, while LTOR increases the potential for the previously mentioned crash types, most people believe that it is no more hazardous than left turn on green. Fleck and Yee (2002) reported that LTOR had a lower collision rate than left turn on green (LTOG). Further confirmation was provided in later studies conducted by Qi et al. (2012), which found that left turn on green resulted in more crashes than LTOR.

While it has been found that the frequency of crashes attributable to LOTR is no higher than that of left turn on green, the safety of LTOR may be debated for the following reasons:

- Most road users believe that LTOR could have adverse safety effects for persons with disabilities, particularly persons with visual impairments (Lord 2002).
- While not unique to LTOR (e.g. drivers also violate red lights and stop signs), the violation rate of LTOR is generally high (Lord 2002).
- While LTOR accounts for very few reported pedestrian collisions, violation of LTOR may not always be the reported cause of the collision, e.g. violation of pedestrian right-of-way, driving under the influence (DUI) and other causes may be listed (Fleck & Yee 2002).

The safety of LTOR may be improved if it is combined with decreased kerb radii and improved sight distance and roadway geometry (Fleck & Yee 2002).

While LTOR is not approved for use in Queensland, it is currently being trialled by Brisbane City Council. Once the evaluation is completed, the Department will review the findings and make a decision on the long-term use of this treatment.

Pedestrian and cyclist treatments

The traffic control and operational treatments previously reviewed primarily target crashes between vehicles. Crash treatments aimed at improving pedestrian and bicycle safety may be required at intersections with a high number of pedestrian- and bicycle-related crashes. A primary key to success is the anticipation of the needs of pedestrians and cyclists during the design of new intersections and intersection improvements.

Austroads (2012) gives the following crash reduction factors for traffic control measures for pedestrian- and cyclist-related crashes:

- 50% decrease in crashes where pedestrian signal phases are added
- 35% decrease in crashes where improved pedestrian signal timing is employed
- 50% decrease in crashes where rest-on-red is employed.

2.3.2 Geometric Improvement Treatments

Geometric improvement treatments involve altering the layout of an intersection in order to address a particular crash type. While they are generally expensive, they have been proven to have the potential to address all intersection crash types involving all road users and can include (Austroads 2012):

- providing left-turn and/or right-turn lanes
- improving the geometry of bicycle and pedestrian facilities
- revising the geometry of complex intersections, which can include large-scale options such as replacing an intersection with a roundabout or staggered T-configuration
- separating grades.

Left-turn and right-turn lanes

Channelisation of turning manoeuvres has the potential to reduce rear-end crashes by providing designated right-turn and/or left-turn lanes that allow for turn movements to occur in a more protected manner, while providing for unobstructed movement of through vehicles. Provision of dedicated right-turn lanes also reduces crashes related to right-turn manoeuvres that conflict with the opposing traffic stream because vehicles are removed from the primary travel lane while drivers wait for an acceptable gap (Lyon et al. 2007). The key to the success of channelising turning manoeuvres is providing appropriate lengths, widths and tapers, such that there is adequate storage capacity in the dedicated turning lanes so that turning vehicles are not forced to queue in adjacent through lanes (Baldock et al. 2005).

Several references provide the following crash reductions attributable to the installation of dedicated right-turning and/or left-turning lanes:

- Lyon et al. (2007):
  - 39% decrease in rear-end crashes
- Austroads (2012):
  - 35% reduction for installation of right-turn lane in general
  - 30% reduction for installation of right-turn lane in signalised intersections
  - 35% reduction for installation of right-turn lane in unsignalised intersections
  - 20% reduction for installation of left-turn lane in general.

Lyon et al. (2007) found that dedicated turn lanes were far more effective in rural areas, especially on two-lane rural roads with a high frequency of rear-end collisions involving a lead vehicle desiring to make a turn. The greater effectiveness of dedicated turning lanes in rural areas is further evidenced by the crash reduction factors stated in Austroads (2012) to range from 40% for a rural unsignalised T-intersection to 30% for a rural unsignalised cross-intersection.
While dedicated right-turn lanes primarily provide for vehicles turning from a main road onto a minor road, treatments are often required for vehicles turning from a minor road onto a major road, particularly for higher mass limit vehicles. Wide median strips are commonly used to provide

storage space such that larger vehicles can make a two-stage crossing of a divided highway. Initially, the driver would traverse the first half of the divided highway and then wait safely for an appropriate gap in the far-side traffic prior to completing the crossing manoeuvre (Tarko, Leckrone & Anastasopoulos 2012).

Conversion of cross-intersection to staggered T-intersections

A more involved geometric intersection crash treatment is the conversion of a cross-intersection into a staggered T-intersection. This effectively decreases the number of conflict points and affects slower speeds on at least one leg of the intersection, which further reduces the likelihood of a serious injury (Candappa et al. 2006, NCHRP 2010). While costly, several studies have investigated the safety effects of staggered T-intersections and have found promising results:

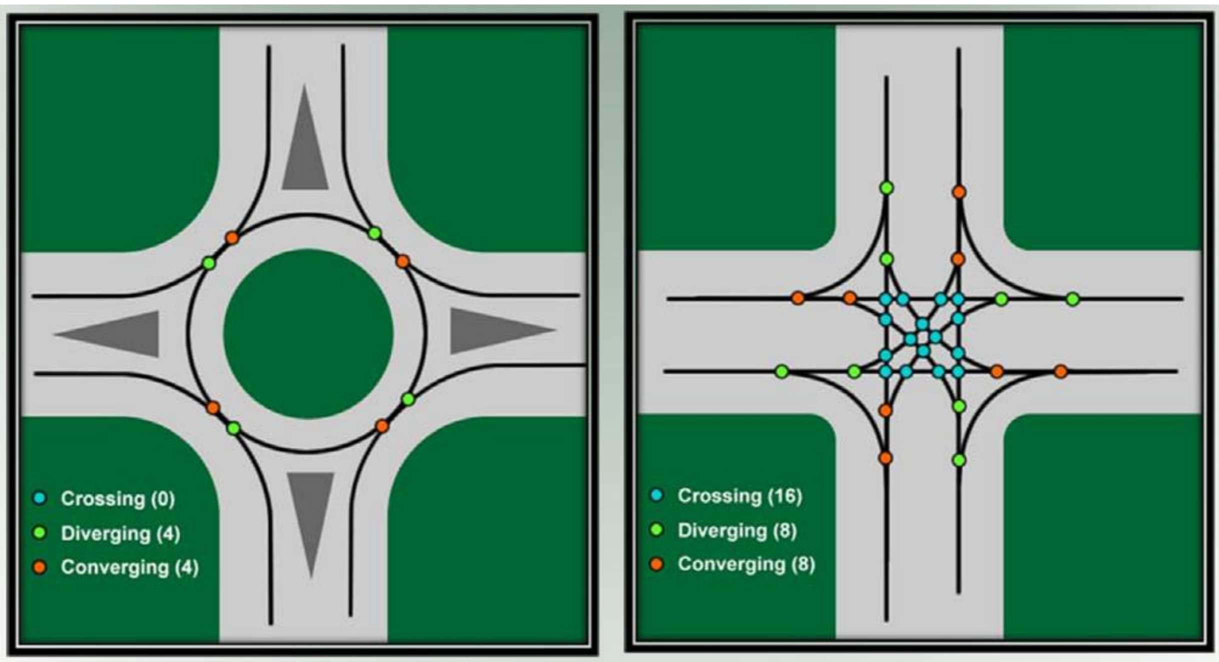
- Candappa et al. (2006):
  - 94% decrease in serious injury crashes (i.e. almost complete elimination of serious injury crashes)
- Austroads (2012):
  - 35% reduction where minor road traffic is less than 15% of main road traffic
  - 25% reduction where minor road traffic is between 15–30% of main road traffic
  - 35% reduction where minor road traffic is greater than 30% of main road traffic.

Signalised and unsignalised roundabouts

Roundabouts are commonly used to replace signalised intersections in an effort to reduce the number of right angle crashes and crashes related to high speeds, both of which lead to crashes of a more serious nature (Austroads 2015b). They are also used to treat the problem of excessive queuing and delays caused by high directional flows (Andjic 2013). It should be noted that speed reduction will likely occur on the roundabout, but the reduction will only occur at the approaches if the approach geometry is modified. While among the most expensive of intersection crash treatments, research has shown that roundabouts, whether signalised or unsignalised, have safety advantages over signalised intersections and are suitable where other crash treatments have not proven effective.

The possibility for a crash to occur at a roundabout is diminished as roundabouts inherently have fewer conflict points than a comparably sized (i.e. equal number of lanes) signalised intersection (refer Figure 2.1). Also, through the impact angles induced by the geometry of a roundabout and the speed reductions required to negotiate the roundabout safely, impact forces are greatly reduced to levels which are typically low risk to vehicle occupants (Candappa et al. 2006). In addition to impact forces being reduced to low-risk levels, the physical separation of vehicles on a collision course by a raised roundabout virtually eliminates the potential for head-on collisions (Alisoglu 2010).

Figure 2.1: Signalised intersection vs. roundabout conflict point comparison



Source: FHWA (2007).

Several studies and guides provide the following crash reductions for converting intersections to roundabouts:

- NCHRP (2008):
  - 35% in total crashes and 77% in injury crashes for all intersection types
  - 72% in total crashes and 87% in injury crashes for rural two-way stop-controlled intersections
- Alisoglu (2010):
  - 76% in the United States
  - 75% in Australia
  - 86% in Great Britain
- Campbell, Jurisich and Dunn (2012):
  - 11-40% for three-arm roundabouts
  - 17-50% for four-arm roundabouts
- Austroads (2012):
  - 70% for rural roundabouts
  - 55% for urban roundabouts
- iRAP (2010):
  - 60% or more for roundabouts in general.

Although roundabouts have significant safety benefits over signalised intersections, lower risk crashes may still be prevalent. Rear-end crashes, which commonly occur at roundabout entries, can be attributed to inadequate crash treatments aimed at reducing approach speeds (Polders et al. 2015). Campbell et al. (2012) noted that excessive sightlines to the right can encourage drivers to approach roundabouts at higher than desirable speeds, which subsequently increases the risk of rear-end crashes. Also, the safety effects of roundabouts are not equally distributed across the different types of road users because they seem to induce a higher number of cyclist-involved crashes (Polders et al. 2015).

Several studies have noted the importance of providing pedestrian and cyclist facilities namely, pedestrian signals and zebra crossings, at roundabouts, while ensuring that the alignment of the approaches promotes slower approach speeds (Ridding and Phull 2009; Campbell et al. 2012). Provision of pedestrian facilities at roundabouts decreases the potential for severe pedestrian and cyclist injuries; however, the effect is likely to be limited if the facilities are located far enough away from the intersection or the approach in which they are located does not have sufficient horizontal deflection to encourage slower speeds. As the critical threshold speed for vehicle-pedestrian collisions is only 20 km/h, it is likely that vehicles will be travelling above that speed upon approach to the roundabout (Austroads 2015b).

Campbell et al. (2012) found that zebra crossings are relatively safe if located within 20 m of a roundabout due to the lower speeds at which approaching and exiting vehicles should be travelling. Pedestrian signals were also noted as a viable alternative;, however, pedestrian wait times would need to be set low enough in order to discourage pedestrians from jaywalking. Also, pedestrian signals would have to be located at a distance from the roundabout such that queueing through the roundabout would not occur.

The increased numbers of rear-end crashes and cyclist-involved crashes that may occur at a roundabout can be controlled by the installation of part-time or full-time traffic signals at the roundabout. Signals assist in regulating the speed of the circulating traffic, which improves safety, particularly for cyclists. They have been proven to reduce:

- crashes attributable to poor judgement of gaps by drivers entering a high-speed flow of circulating traffic (Department for Transport 2009)
- rear-end crashes between vehicles waiting to join the roundabout as the priority decision is altered from gap acceptance to simply obeying a red light (Austroads 2015b).

Another primary advantage of signalised over unsignalised roundabouts is that the delays at a signalised roundabout remain quite constant when flows increase, compared with unsignalised roundabouts where delays can rise to an unacceptable level (Bernetti, Dall' Acqua & Longo 2003). This is particularly prevalent during peak traffic periods. It is more evident in larger, multi-lane roundabouts with a greater number of entries and higher traffic flows and indirectly leads to fewer crashes as shorter delays discourage drivers from careless driving.

Table 2.1 provides a breakdown of reductions (and increases) in crash types attributable to the installation of signalised roundabouts.

Table 2.1: Effect of signalised roundabouts on crashes

Crash type	Crashes before	Crashes after	Change (%)
Total collisions	384	277	–28 %
Involving a motorbike	85	63	–26 %
Involving a cyclist	70	14	–80 %
On a wet road surface	79	49	–38 %
During hours of darkness	101	73	–28 %
Entering a roundabout	71	30	–58 %
Speed-related crashes	26	44	+69 %

Source: Campbell et al. (2012)

Table 2.1 shows that signalised roundabouts provide for the safety of all road users; however, studies have shown that the safety of part-time signalisation is questionable (Ridding and Phull 2009). This is because part-time signals can lead to driver confusion as to whether or not the signals are in service. Also, part-time signals do not provide for the safety of pedestrians with visual impairments as there is no effective way of indicating in a non-visual way that the signals are not operational (Department for Transport 2009).

While signalised roundabouts have safety advantages over unsignalised roundabouts and signalised intersections, there has been agreement among jurisdictional experts that signalising existing roundabouts is more attractive than installing a signalised roundabout at intersections with existing priority control or signals (Austroads 2015b).

Grade separation

Grade separation can be achieved by the construction of interchanges or overpasses. This can significantly reduce intersection crashes by stopping conflicting intersection movements from occurring. Overpasses and interchanges are very costly and are usually built as part of a freeway system where large traffic flows justify the cost (iRAP 2010). Austroads (2012) indicates a crash reduction of 55% for cross-intersections and 30% for Y-intersections. iRAP (2010) indicates a 25-40% crash reduction for grade separation.

2.3.3 Driver Awareness Treatments

Driver awareness treatments aim to alert the driver of the presence of an upcoming intersection and are typically utilised at intersections that have a high level of crashes that can be attributed to poor visibility, signage and delineation (NCHRP 2004, NZ Transport Agency 2013). The treatments should not increase driver confusion.

Delineation

Clear intersection delineation is required to indicate the presence of an intersection to drivers as well as the expected manoeuvres likely to be undertaken at and on the approaches to the intersection. If drivers are unaware of the intersection, there is potential for high-speed crashes to occur, resulting in severe outcomes. Clear delineation may reduce crashes, reduce vehicle speeds, increase the awareness of the intersection, and provide a clear path to drivers (iRAP 2010).

Delineation treatments may include improvement to or installation of linemarking, signage, street lighting and traffic islands. Many of these are relatively low cost treatments that can provide safety benefits to road users. Several studies provide the following crash reduction factors for delineation improvements:

- Austroads (2012)
  - installation of stop signs:T-intersection 15%, cross-intersection 30%, four-way stop signs at cross-intersection 60%
  - installation give-way sign: 25% all intersection types
  - installation general channelisation: 30%
- iRAP (2010)
  - general delineation improvements: 10 - 25%.

Street lighting

Hallmark et al. (2008) evaluated the effectiveness of commonly adopted treatments aimed at reducing the number of night-time crashes. The study noted that street lighting can illuminate areas of an intersection where drivers require additional light so that they are able to avoid other vehicles and pedestrians while negotiating the geometry of the intersection. Edwards (2015) examined the relationship between the level of street lighting and night-time crash frequency. It was concluded that:

- a unit increase in lux/fc at a lit intersection decreased the night-time crash rate by 9%
- a unit increase in lux/fc at an unlit intersection decreased the night-time crash rate by 94%.

Several other studies have examined the effectiveness of providing street lighting at unlit intersections:

- Wortman et al. (1972) cited in Edwards (2015):
  - 30% decrease in night-time crash rate
- Preston & Schoenecker (1999) cited in Edwards (2015):
  - 40% decrease in overall night-time crash rate
  - 20% decrease in fatal and personal injury crashes
- The Arizona Department of Transportation (2009)
  - 30% decrease in all night-time crashes
  - 42% decrease in fatal and injury crashes.

Hallmark et al. (2008) noted that another purpose of street lighting is destination lighting. This involves mounting a street light on the utility pole closest to an intersection while remaining far enough away such that it does not supplement vehicle headlights. In this instance, the street light simply indicates the presence of an intersection. The adequate lighting of an intersection would then be achieved by the use of an overhead flashing beacon. While the use of overhead flashing beacons has proven to be a cost-effective treatment, several studies have noted that the use of overhead beacons has not been consistently effective in reducing crash rates (Tarko, Leckrone & Anastasopoulos 2012).

Increased retro-reflectivity of signs

While street lighting alone has the potential to reduce crash rates, it generally has to work in conjunction with other intersection crash treatments such as stop signs. Persaud et al. (2008) investigated the effects of increasing the retro-reflectivity of stop signs by estimating the expected change in crash rates. The purpose of this treatment is to reduce the number of rear-end and right angle crashes by alerting the driver to the presence of an intersection earlier.

A key finding was that the effectiveness of the signs was not dependent on whether the roads were rural or urban, but that it was dependent on intersection volume and the number of intersection legs. There was almost no reduction in the number of crashes at cross-intersections but a 23–26% decrease at T-intersections and 14–25% reduction at lower volumes (AADT< 1200) for motorists approaching the intersection along minor roads. The reason provided was that, at the higher volume intersections, there were more visual cues for the approaching minor road motorist (such as other traffic stopped in front of the driver) that the intersection is stop-controlled (Persaud et al. 2008).

Vehicle activated signals

Vehicle activated signals aim to inform a driver of safe gaps in order to reduce the number of right angle crashes. This treatment involves using camera sensors to detect vehicles approaching from the side roads within a specific time frame, triggering sign lights on the main roads, which are lit to warn vehicles on the main road that vehicles are approaching from the side road (Bradshaw, Bui & Jerewicz 2013).

Bradshaw et al. (2013) noted that, while a broader review of this method would be required before the results of the study could be transferrable to other locations, it was found that vehicle actuated signals have the potential to reduce intersection crash rates by the following:

- 18% reduction in fatal crashes
- 12% reduction in serious injury crashes
- 8% reduction in casualty crashes.

Taking vehicle activated signs one step further, infrastructure-based collision warning systems are also believed to have the potential to reduce right angle crashes. Numerous studies have been carried out with several variations proposed. These systems would require the installation of a detector that detects the nearest vehicle approaching the intersection and measures its position and speed in order to determine its acceleration rate. Taking into account driver perception-reaction time, the system then estimates the distance and time needed for the turning vehicle to accelerate to that speed (Dabbour & Easa 2014). These systems aim to identify safe gaps in traffic and then communicate them to the drivers so that they can make an informed decision about entering a major traffic stream (Donath et al. 2007).

While they are yet to be proven, it can be concluded that infrastructure-based collision warning systems would provide safety benefits as they have the potential to assist in avoiding right angle crashes, which are among the more costly crashes.

2.3.4 Driver Compliance Treatments

Driver compliance treatments aim to enforce traffic rules and regulations by creating situations where it would be undesirable for a driver to disobey traffic laws. Disobedience of traffic rules and regulations may result in drivers being issued with a punishment (e.g. fine) and careless driving on an approach to an intersection may result in a loss of vehicle control (e.g. excessive speed along a curved approach). Driver compliance treatments commonly involve (Austroads 2015a, Corben et al 2005; Freeman et al. 2008):

- deployment of red-light cameras
- deployment of fixed or mobile speed cameras
- vertical deflections on intersection approaches
- lane narrowing.

Red-light and speed cameras

Red-light cameras and signs informing the public of their presence are a common treatment for signalised intersections with a high frequency of right angle and rear-end crashes attributable to drivers who intentionally disobey red lights.

While it has been found that red-light cameras have the potential to decrease right angle crashes, they can also increase rear-end crashes due to the abrupt stopping of leading vehicles with following vehicles not having enough time to act accordingly. Several studies and reports have estimated the following crash reduction factors for red-light cameras:

- De Pauw et al. (2014) (based on 77 locations):
  - 26% decrease in casualty crashes
  - 44% decrease in right angle crashes
  - no change in rear-end crashes
- Austroads (2012):
  - 5% decrease in all crashes.

De Pauw et al. (2014) also noted that, while red-light cameras may not necessarily result in a decrease in rear-end crashes, future research is likely to develop measures that will act in combination with red-light cameras and address this unintended effect. The treatments include vehicle technologies such as advance warning and automated braking systems. Further discussion on these systems can be found in Section 2.3.8.

As mentioned previously, red-light cameras have the potential to increase the number of rear-end crashes. However, research has shown that deploying approach-speed cameras may decrease the frequency of rear-end crashes due to slower speeds, which result in longer times for driver reaction. The key to successful speed cameras is the prioritisation of intersections that require them. Austroads (2012) gives the following crash reduction factors for the different types and locations of speed cameras:

- 20% decrease for mobile covert speed cameras in urban areas
- 20% decrease for mobile covert speed cameras in rural areas
- 30% decrease for fixed overt speed cameras in urban areas
- 30% decrease for fixed overt speed cameras in rural areas.

Lane narrowing

Lane narrowing is a physical gateway treatment (Austroads 2010b) that is commonly adopted on the minor approaches of rural intersections in order to encourage more controlled stops from road users by effectively forcing the driver to reduce speed in order to safely and comfortably negotiate the approach. Lane narrowing treatments aim to prevent right angle crashes due to vehicles entering the intersection without a safe gap and to prevent rear-end crashes due to vehicles travelling at excessive speeds upon approach. Common approach speed treatments include (FHWA 2009):

- lane narrowing using rumble strips inside and parallel to the edge lines
- lane narrowing using raised pavement markers in lieu of rumble strips.

Gross, Jagannathan and Hughes (2008) studied the effectiveness of lane narrowing treatments on intersections that were known to be difficult to detect for approaching drivers and had speeding issues and a lack of compliance with existing stop signs. Two lane narrowing treatments were investigated, the first of which involved installing rumble strips on the outside shoulders of the road surface and in a painted yellow median island. The second treatment involved installing separator islands on the minor road approaches in order to channelise the approaches. These islands were then supplemented with stop signs, the objective being to provide stop sign redundancy and increase driver compliance with the stop signs.

While only a small number of sites were treated and tested, Gross, Jagannathan and Hughes (2008) found that the measures had the potential to reduce approach speeds. Their primary findings were as follows:

- 5.6 km/h decrease in mean speed
- 30 – 83% decrease in total crashes.

Findings from other studies include:

- Austroads (2012):
  - 30% decrease in crashes for general channelisation installations
  - 30% decrease in crashes for splitter island installations
  - 15% decrease in crashes for mountable median installations
  - 25% decrease in crashes for non-mountable median installations
  - 25% decrease in crashes for transverse rumble strip installations
- Arizona Department of Transportation (2009)
  - 53% decrease in crashes for transverse rumble strip installations.

Vertical deflection

Vertical deflections on approaches utilise protrusions from the intersection surface to promote lower approach speeds and can be in the form of:

- raised stop bars
- speed platforms
- raised intersections.

Austroads (2011) reported that speed humps, a common form of vertical deflection, were effective in reducing the 85th percentile speed in the order of 5–10 km/h. It is intuitive that this would lead to less severe crashes. Austroads (2012) and iRAP (2010) indicate a 20% and 25–40% crash reduction for traffic calming in general, which includes vertical deflection treatments.

While this particular treatment does not affect the number of conflict points inherent in a particular intersection, speed reduction could be sufficiently significant such that there are substantial safety improvements. It should be noted, however, that vertical deflections can affect emergency vehicle response times. It should also be noted that vertical deflections are not always able to guarantee low speeds. For example, arterial roads with design speeds of 70 km/h would require vertical deflections designed for a 60 km/h traverse, which is far higher than the critical threshold speed for most crash types (Austroads 2015b). As such, vertical deflections are most suitable on lower speed roads.

2.3.5 Access Management Treatments

Access management treatments aim to restrict access to commercial properties in close proximity to intersections by relocating driveways to minor roads and restricting turns into and out of commercial property driveways. Effective access management has the potential to decrease the number of crashes attributable to driveway access.

Possible access management treatments include (NCHRP 2004):

- restricting vehicles from crossing the median near intersections which has the potential to decrease the number of right-through crashes between vehicles turning right into the driveway and through vehicles, which are typically more serious
- relocating commercial property driveways from major roads to minor roads, which shifts the conflict point to a road with lower speeds, lower traffic volumes and, therefore, lower crash frequency and severity
- restricting turns into and out of the driveway to left-in and left-out only, which will eliminate the conflict point between vehicles turning right into the driveway and through vehicles.

iRAP (2010) provides a crash reduction value of 25-40% for restricting or combining direct access points.

2.3.6 Pedestrian Signal Crossing Technology

Retting, Chapline and Williams (2002) found a 37% reduction in pedestrian and cyclist crashes when signal timing was changed. The introduction of newer technology means that pedestrian crossings can provide better safety and amenity to pedestrians and potentially reduce the delay to motorists. The puffin crossing uses sensors to detect the presence of pedestrians waiting to cross, pedestrians crossing and vehicles coming from both sides. It is different from the normal pelican crossing in that it allocates crossing walk times to suit the traffic volume and time taken by pedestrians to cross the road safely (as with vehicle actuated traffic signals). It thus provides variable walking times for crossing. Operation starts when a pedestrian presses a push button. The pedestrian wait area is recorded by an above-ground sensor. Detection from both the push button and above-ground sensors is required to provide a valid call input. Thus, if a pedestrian leaves the wait area after pressing the push button, the request to cross is cancelled.

Maxwell et al. (2011) evaluated the safety benefit of puffin facilities compared with pelican crossings and reported that puffin crossings reduce both driver and pedestrian delays and improve pedestrian safety, especially for the elderly and for those with mobility issues. They reported a 19% reduction in crashes when pelican crossings were replaced by puffin facilities at 50 mid-block and intersection sites.

2.3.7 Other Infrastructure Treatments

Safety concerns at intersections are not always related to traffic control, intersection geometry, driver awareness, compliance or access management. Changes or additions made to other road infrastructure elements can reduce the frequency of intersection crashes.

Road drainage improvements and pavement resurfacing

Within intersections with poor drainage, the possibility of hydroplaning increases the potential for turning vehicles or cross-street vehicles to be involved in right-through crashes or right angle crashes, which typically have greater consequences. Intersections with pavements that have been subject to polishing and/or rutting also have increased potential for more severe crashes.

High-friction surfacing systems, which typically use much smaller and harder aggregates (e.g. concrete) to make the surface much more resistant to wear and polishing (FHWA 2009), work hand-in-hand with appropriate drainage infrastructure towards preventing intersection crashes attributable to hydroplaning and skidding (NCHRP 2004). The key to success for this strategy is to accurately determine, through routine pavement inspections, which intersections are prone to drainage issues or have been subject to rutting and polishing. Evidence of effectiveness of treatment includes:

- Arizona Department of Transportation (2009)

- 19% reduction in all rear-end crashes
- 39% reduction in all wet pavement-related crashes

- Austroads (2012)
  - 35% decrease in all crashes.

Railway crossing treatments

At-grade railway crossings on intersection approaches have potential safety problems related to vehicles queueing across railway tracks. This situation leads to an increased potential for rear-end crashes, but also leads to the possibility of vehicle-train crashes, which are among the most severe of traffic crashes. Keys to the success of this strategy include (NCHRP 2004):

- appropriately coordinating traffic signals with approaching trains to ensure that the traffic signals allow a queue to clear before the approaching train passes
- an adequate warning system including a gate
- taking proper account of potential traffic queue lengths during periods of congestion.

Austroads (2012) provides the following crash reduction factors for warning treatments at at-grade railway crossings:

- 25% decrease in crashes where signage is implemented
- 50% decrease in crashes where signage is upgraded to lights and bells
- 45% decrease in crashes where lights and bells are upgraded to barriers
- 70% decrease in crashes where signage is upgraded to barriers.

Roadside furniture

At intersections, roadside furniture such as utility poles and trees are potential hazards if they are not located at an appropriate distance from edge lanes or if they are not adequately protected. For example, roadside cantilever gantries along highways typically use large steel sections for their supporting poles, which have low frangibility. A collision with a cantilever gantry pole potentially has severe consequences. Unlike true rural intersections that are rarely signalised, almost all urban intersections have traffic signals as part of their roadside furniture.

Intersections with a high number of crashes attributable to roadside furniture should have any hazardous furniture relocated, protected or removed, if possible (NCHRP 2004). The key to success for this strategy is to ensure that any safety benefits gained from the relocation of roadside furniture are not offset by safety hazards related to the protected/relocated furniture. For example:

- the new location of the roadside furniture should not create a sight distance obstruction
- night-time visibility must not be compromised if lighting poles are to be relocated.

It has been noted, though, that it is difficult to quantify the effectiveness of roadside furniture relocation given the range of conditions and very low frequency of such conflicts at any one intersection. iRAP (2010) indicates a 25–40% crash reduction for the relocation of roadside hazards, noting that this value is not specific to intersection crashes.

2.3.8 Vehicle Technology and Design

As mentioned in Section 2.2, most crash reduction treatments that have been researched extensively are infrastructure based. So far, several vehicle-mounted crash reduction treatments have been proposed or are currently available, but none have been widely deployed and tested. This is most likely due to the fact that, as crashes occur rarely, a large number of vehicle-mounted crash reduction treatments would have to be deployed and tested over a long period in order to achieve statistically significant results. Further to this, limited market penetration of currently available devices makes real-life trials difficult (Demmel, Larue & Rakotonirainy 2014).

The following vehicle-mounted crash reduction treatments are available, under development or have been proposed:

- collision avoidance systems
- retro-reflective materials/stickers
- cooperative ITS.

Some technologies currently available on new vehicles include adaptive cruise control, advanced warning systems and autonomous braking systems. For example, marketed Mercedes Benz S-class vehicles have autonomous braking systems (Park, Chen & Hourdos 2011).

As stated in Section 2.2, most infrastructure-based treatments generally result in a decrease in the number of right angle or head-on intersection crashes; however, they may not necessarily result in a decrease in the number of rear-end crashes. As many vehicle-mounted crash treatments are intended to increase a following vehicle's awareness of the leading vehicle, e.g. by applying retroreflective material to the rear of the leading vehicle (Baldock et al. 2005), it is intuitive that they have the potential to reduce the number of rear-end crashes.

Park, Chen & Hourdos (2011) utilised the inverse of time-to-collision and deceleration rate differences as possible triggers for preventing rear-end crashes. It was suggested that these triggers could be built into vehicles in the form of advance warning systems or autonomous braking systems. The study found that, while autonomous braking systems would not have avoided all of the observed crashes, they helped to reduce the number of crashes and crash severity. It is intuitive that the lower speeds inherent in an autonomous braking system would result in lower crash severity. By contrast, it was found that advance warning systems were not very effective for avoiding rear-end crashes as drivers' reaction times were not properly accounted for.

Other vehicle-mounted crash treatments such as cooperative ITS and vehicle telematics remain largely at the experimental stages of development. For example, the use of cooperative ITS has not been comprehensively evaluated and most studies that have aimed to evaluate it, have not considered important factors such as human factors and the limitations of wireless network reliability (Demmel, Larue & Rakotonirainy 2014). Vehicle telematics are of particular interest, though, as it is believed that driver behaviour may change for the better if drivers are aware that their behaviour is being monitored. With further developments in vehicle-mounted crash treatments and intelligent transport systems, the future may consist of interconnected fleets of driverless vehicles, which may 'talk' to one another and the road, thereby reducing the potential for crashes (Royal Automobile Club 2014).

2.4 Summary Findings

A summary of treatment effectiveness determined from the literature review is provided in Table 2.2. The table also provides an indication of cost and treatment life (Austroads 2015c).

Table 2.2: Summary of treatments and their effectiveness

Treatment	Crash type	Effectiveness (crash reduction factor)	Cost (high, medium, low)	Treatment life
Traffic control and operation treatments				
Signalisation of intersection	All casualty	30–40%	Medium	10–20 years
Dedicated right-turn phase	All casualty Right-angle and right-through crashes	15–35% 35–60%	Low–medium	5–10 years
Left turn on red	Not available	–	–	–
Installation of pedestrian signal	Pedestrian	50%	Medium	10–20 years
Geometric improvement treatments				
Left-turn lanes	All casualty	20%	Low–medium	5–10 years
Right-turn lanes	All casualty	30–35%	Low–medium	5–10 years
Conversion to staggered T-intersection	All casualty Serious injury	25–35% 94%	Medium–high	Not provided
Installation of roundabouts	All casualty	11–86%	Medium–High	10–20 years
Grade separation	All casualty	25–55%	High	>20 years
Driver awareness treatments				
Delineation – install stop and give way signs	All casualty	15–60%	Low	1–5 years
Delineation - general	All casualty	10–25%	Low	1–5 years
Street lighting	Night-time casualty	30–40%	Medium	10–20 years
Increased reflectivity of signs	All casualty	0–26%	Low	1–5 years
Vehicle activated signs	All casualty Fatal and serious injury	8% 12–18%		
Driver compliance treatments				
Red-light cameras	All casualty Right angle	5–26% 44%		
Speed cameras	All casualty	20–30%		
Speed management (lane narrowing and vertical deflection)	All casualty	15–40%	Medium–high	10–20 years
Access management treatments				
Restricting vehicle access near intersections	All casualty	25–40%	Medium–high	10–20 years
Other infrastructure treatments				
Road resurfacing	All casualty Rear-end	35% 19%	Low–medium	5–10 years
Railway crossing treatments	All casualty	25-70%	Medium	10–20 years
Roadside furniture	All casualty	25-40%	Low–medium	5–10 years

3 INTERSECTION CRASH ANALYSIS

The Queensland Department of Transport and Main Roads provided Queensland crash data for:

- fatal crashes from January 2007 to 31 March 2015
- hospitalisation crashes from January 2007 to 31 December 2013
- medical treatment and minor injury crashes from January 2007 to 30 June 2012
- property damage only crashes (PDOs) from January 2007 to 31 December 2010.

Five years of injury crash data (from 2007 to 2011) comprising minor injury, medical treatment, hospitalisation and fatal crashes have been analysed. PDOs have been excluded from this data analysis.

Between 2007 and 2011, there were a total of 69 533 injury crashes recorded on Queensland roads, of which 30 716 were intersection crashes. In all, intersection crashes accounted for 44% of all injury crashes and 40% of FSI crashes during the five-year period. On state-controlled roads, intersection crashes accounted for 40% of injury crashes and 36% of FSI crashes between 2007 and 2011, even though intersections accounts for less than 5% of the network.

Table 3.1: Summary crash data (2007-11)

Road type	Intersection crashes		All injury crashes		Proportion of intersection crashes	
	FSI	Total injury crashes	FSI	Total injury crashes	FSI	All injury crashes
State roads	4 603	12 553	12 685	31 260	36%	40%
Local roads	6 681	18 163	15 192	38 273	44%	47%
Both	11 284	30 716	27 877	69 533	40%	44%

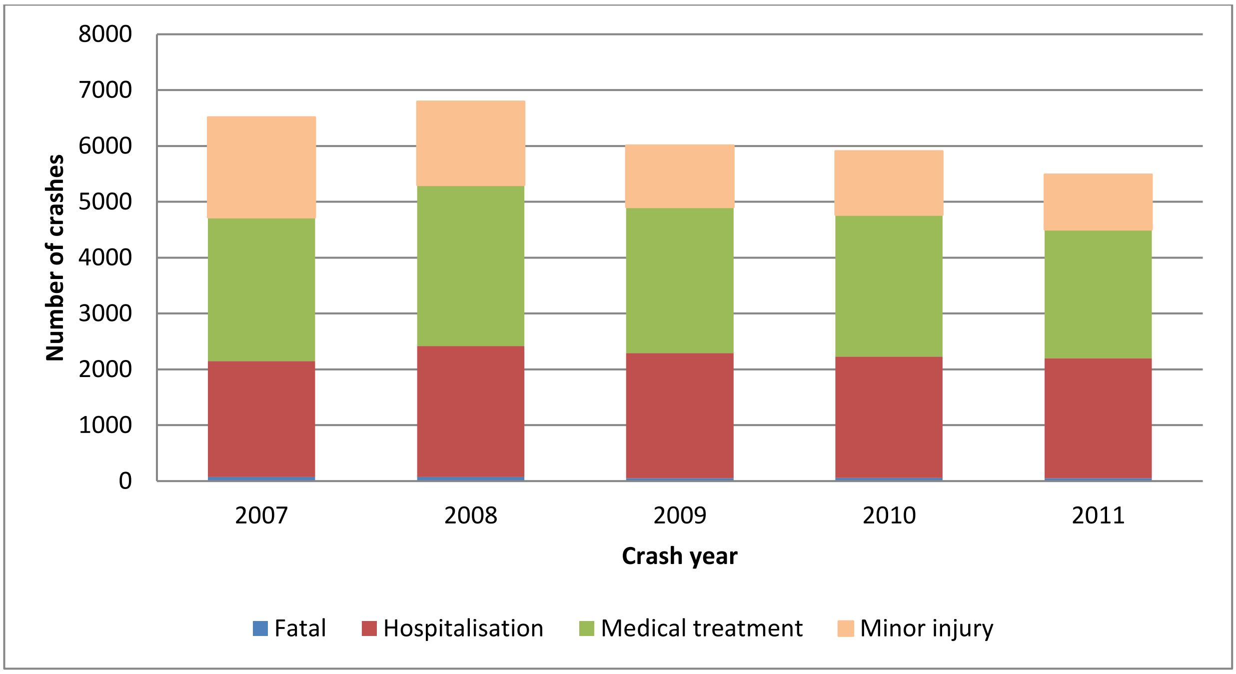
Intersection crashes have been categorised by the following road features:

- cross-intersections
- interchanges
- multiple road intersections
- roundabouts
- T-junctions
- Y-junctions
- median openings
- merge lanes
- railway crossings.

3.1 Annual Distribution of Intersection Crashes

Figure 3.1 shows the annual intersection crashes from 2007 to 2011. There has been a gradual decline in intersection crashes since 2008, with an overall reduction of 15% over the five years. The FSI crash numbers peaked in 2008 at 2417, and have decreased gradually since then. No such decline is observed in fatal intersection crashes. Overall, 40% of the intersection injury crashes occurred on state-controlled roads.

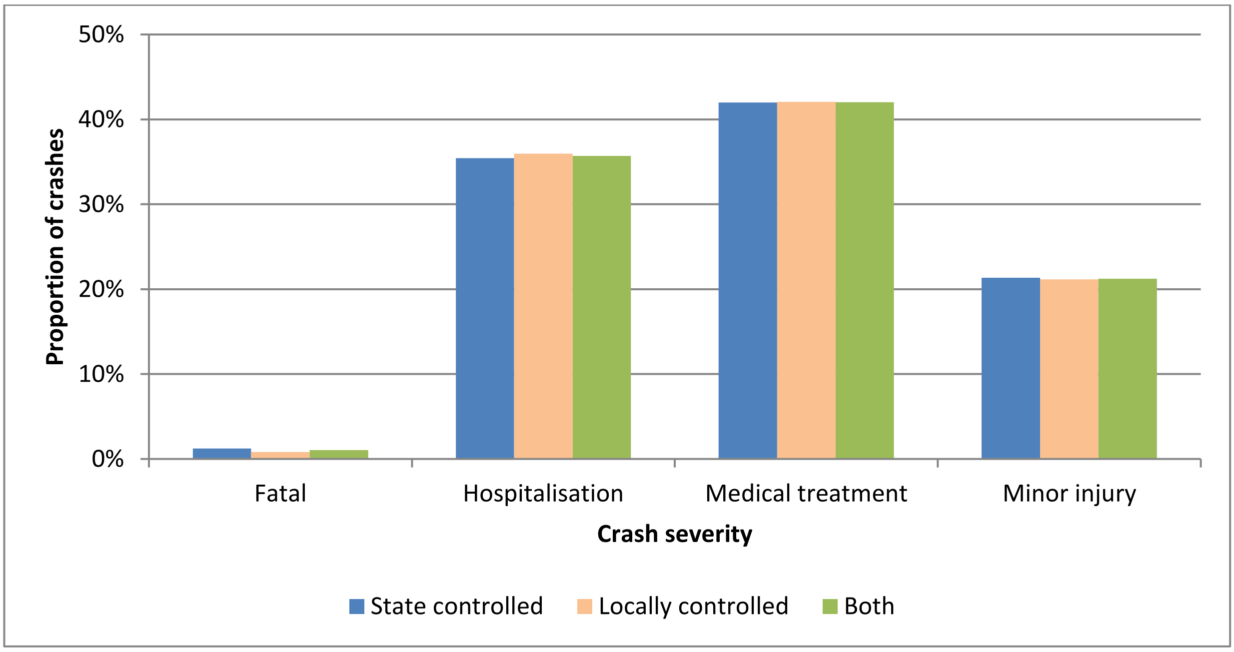
Figure 3.1: Intersection injury crashes by year and severity (2007–11)



3.2 Intersection Injury Crash Severity

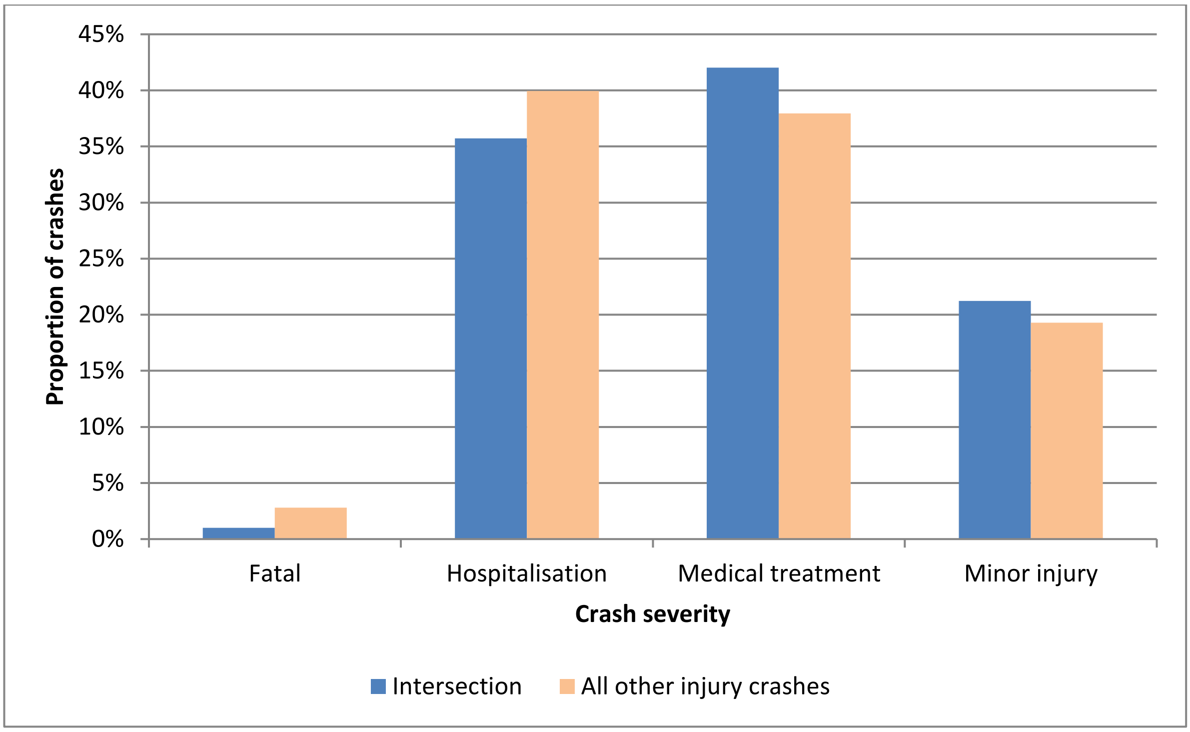
Figure 3.2 shows the severity of intersection injury crashes by road authority. The proportion of intersection crashes that resulted in fatalities is slightly higher on state-controlled roads than on locally controlled roads.

Figure 3.2: Intersection crashes by road authority and severity (2007–11)



A lower proportion of intersection crashes resulted in FSI compared to other crashes (Figure 3.3). About 37% of intersection crashes were FSI crashes compared to 43% for all other crashes.

Figure 3.3: Crash severity comparison between intersection crashes and all other injury crashes (2007–11)



3.3 Intersection Injury Crashes by Intersection Type

Figure 3.4 shows the intersection injury crashes by intersection type. T-junctions accounted for the highest proportion of intersection crashes with 47%, followed by cross-intersection (34%). It should be noted that there are more of these two intersection types on the network.

Figure 3.5 shows the intersection injury crashes by intersection type and severity. Crashes at railway crossings were the most severe, with 52% of crashes resulting in FSI. This was followed by intersections with multiple roads, with 42% resulting in FSI, then cross-intersections with 38%. Though the numbers are small, a high proportion of crashes at railway crossings (9%) and merge lanes (3%) resulted in a fatal crash.

Figure 3.4: Intersection injury crashes by intersection type (2007–11)

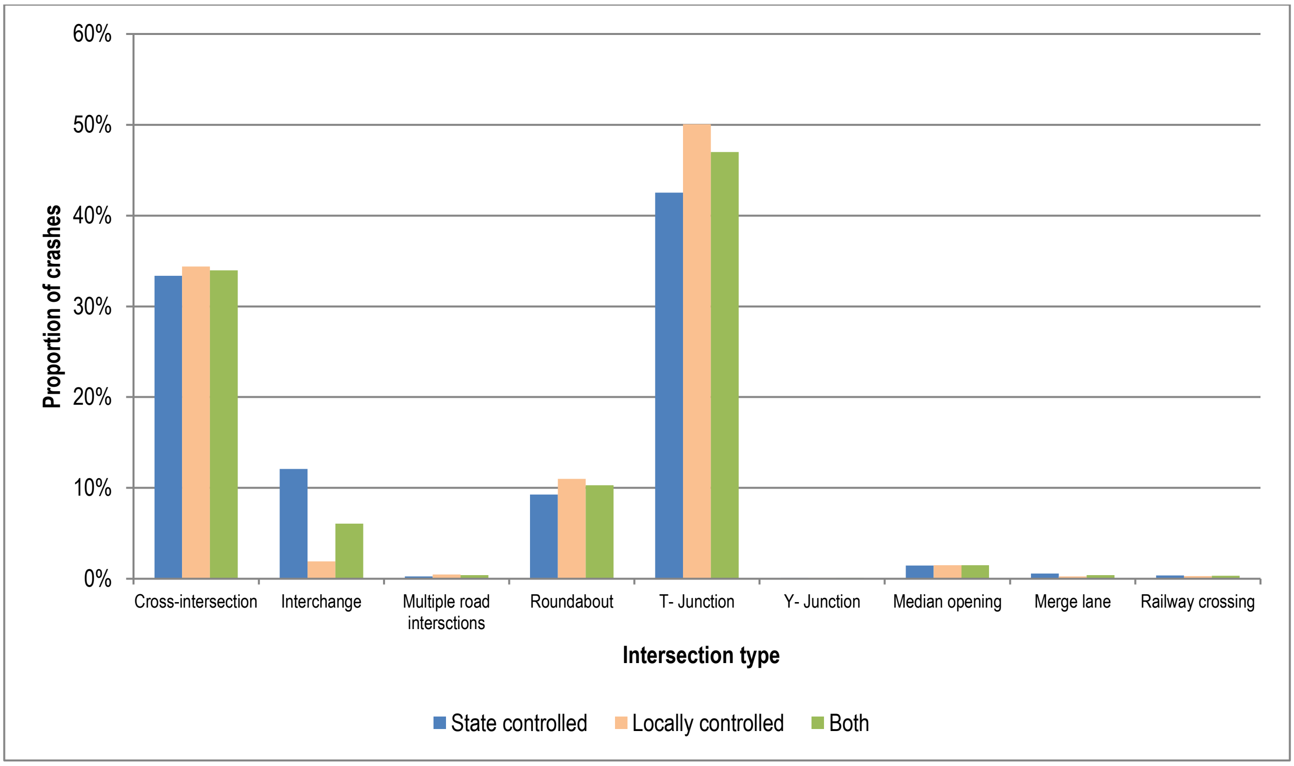
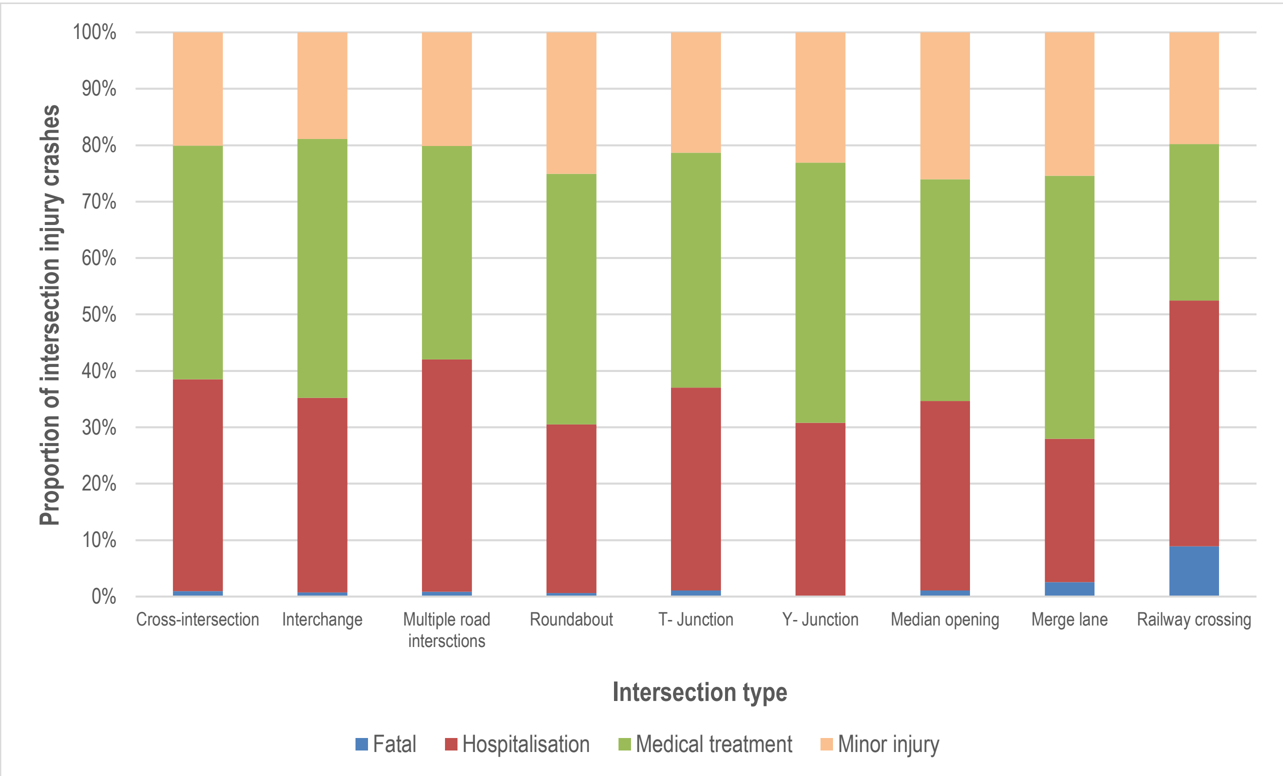


Figure 3.5: Intersection injury crashes by intersection type and severity (2007–11)



3.4 Intersection Injury Crashes by Crash Type

Figure 3.6 shows the intersection injury crashes by crash type. The highest proportion of intersection crashes were angle crashes (57%) followed by rear-end crashes (21%), and then hit-object (10%). State roads recorded a higher proportion of rear-end injury crashes, but recorded lower proportions of angle and pedestrian crashes compared to local roads.

The main crash types at cross-intersections were angle and hit pedestrians (Table 3.2). Most of the intersection rear-end injury crashes occurred at T-junctions (55%) and cross-intersections (24%). About 86% of intersection angle injury crashes occurred at T-junctions (43%) and cross-intersections (43%).

Figure 3.6: Intersection injury crashes by crash type (2007–11)

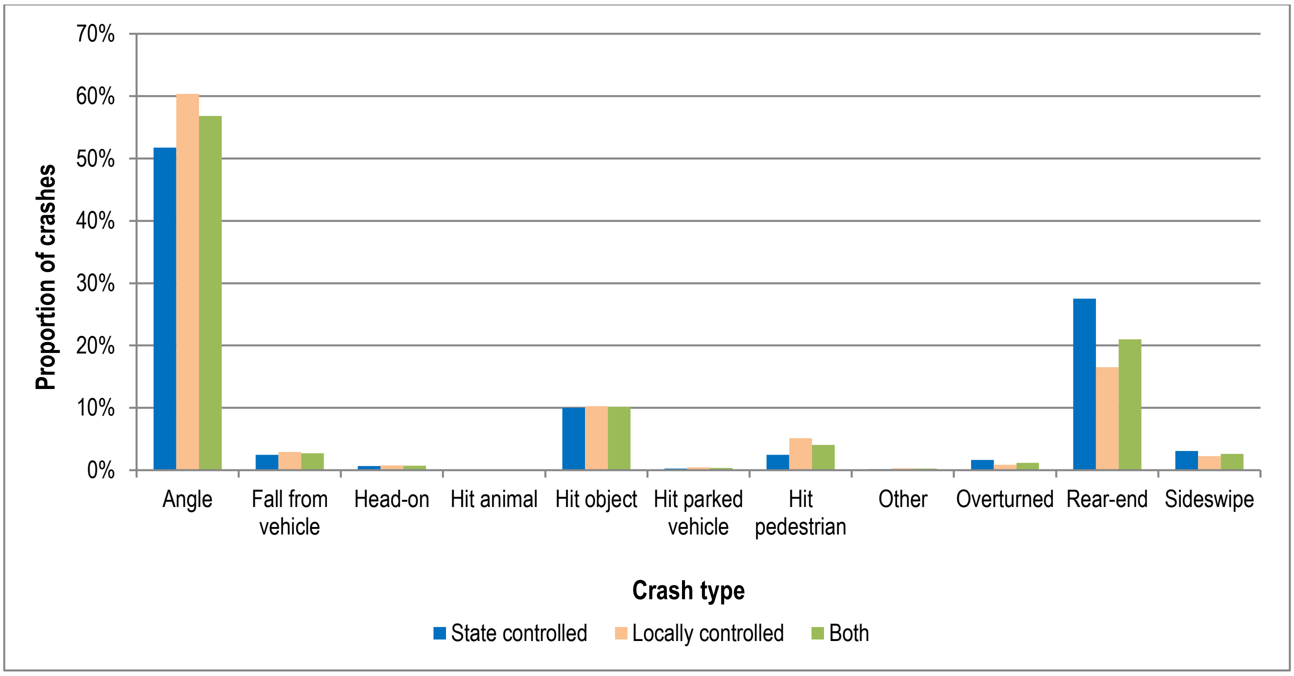


Table 3.2: Intersection injury crashes by intersection type and crash type (2007–11)

Intersection type	Angle	Fall from vehicle	Head-on	Hit animal	Hit object	Hit parked vehicle	Hit pedestrian	Other	Over-turned	Rear-end	Side-swipe	Total by intersection type
Cross-intersection	42.6%	19.1%	23.6%	10.0%	15.6%	4.3%	43.6%	31.5%	8.2%	24.1%	17.4%	34.0%
Interchange	4.0%	5.6%	8.9%	0.0%	10.3%	9.6%	0.8%	6.8%	22.2%	8.5%	15.3%	6.1%
Multiple road intersection	0.3%	0.4%	0.9%	0.0%	0.4%	0.0%	1.3%	0.0%	0.3%	0.3%	0.7%	0.4%
Roundabout	8.2%	21.3%	5.3%	0.0%	19.2%	6.1%	4.0%	15.1%	11.2%	10.1%	23.3%	10.3%
T-Junction	42.6%	51.6%	57.8%	85.0%	52.0%	73.0%	49.4%	45.2%	55.1%	55.1%	37.7%	47.0%
Y-Junction	0.1%	0.1%	0.0%	0.0%	0.2%	0.0%	0.2%	0.0%	0.3%	0.0%	0.1%	0.1%
Median opening	2.0%	1.1%	1.8%	0.0%	0.8%	1.7%	0.6%	0.0%	0.8%	0.8%	1.2%	1.5%
Merge lane	0.1%	0.6%	1.3%	5.0%	0.7%	5.2%	0.1%	0.0%	0.0%	0.6%	3.9%	0.4%
Railway Crossing	0.2%	0.2%	0.4%	0.0%	0.8%	0.0%	0.0%	1.4%	1.9%	0.4%	0.2%	0.3%
Total by crash type	56.8%	2.7%	0.7%	0.1%	10.2%	0.4%	4.0%	0.2%	1.2%	21.0%	2.6%	100.0%

3.5 Intersection Injury Crashes by DCA Code

Table 3.3 shows the intersection injury crashes by DCA[1] code. DCA code 202 (right-through opposing turn) accounted for the highest proportion of intersection injury crashes with 19%, followed by code 101 (through-through adjacent approaches) at 14% and 104 (through-right adjacent approaches) at 13%.

DCA code 202 accounted for a quarter (25%) of intersection FSI crashes on state-controlled roads, and 19% on locally controlled roads, higher than all 202 intersection injury crashes.

Table 3.3: Intersection injury crashes by intersection type and DCA code (2007–11)

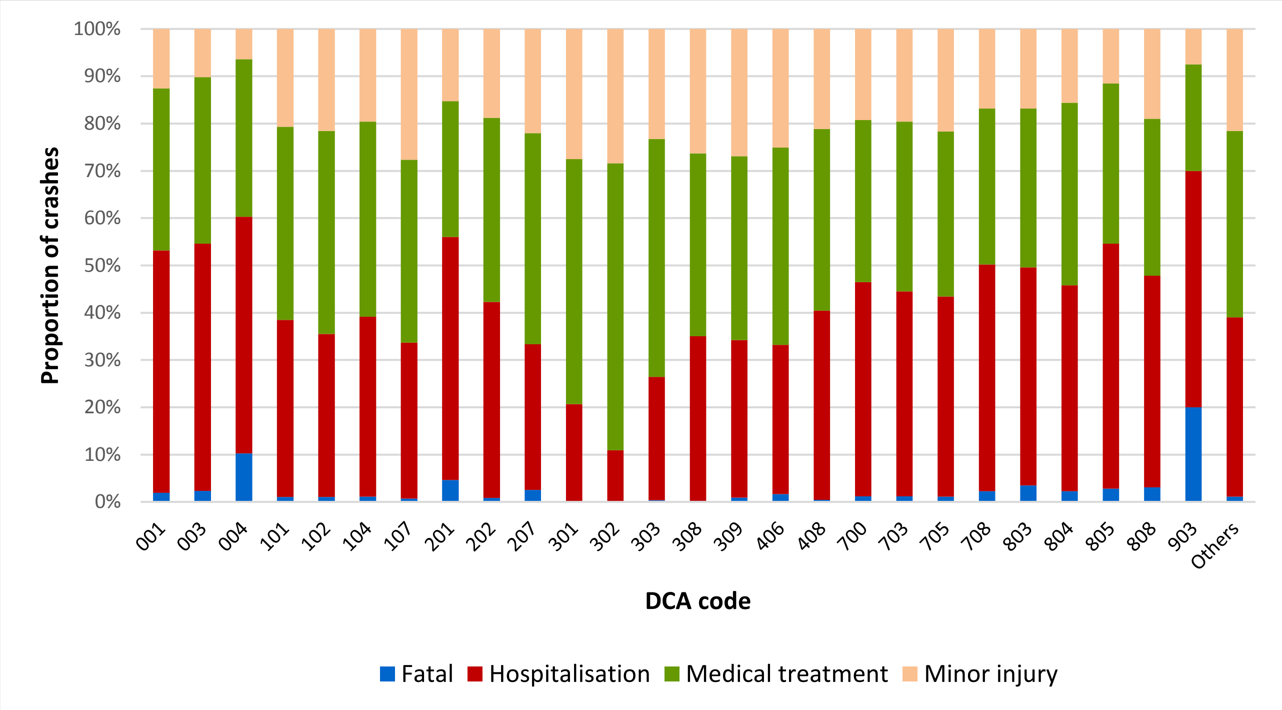
DCA codes[1]	FSI intersection crashes			All intersection injury crashes		
	State-controlled	Locally controlled	Both	State-controlled	Locally controlled	Both
001	1.8%	3.3%	2.7%	1.1%	2.4%	1.9%
003	1.6%	2.7%	2.3%	1.0%	1.9%	1.5%
004	0.3%	0.5%	0.4%	0.1%	0.3%	0.3%
101	10.7%	18.1%	15.0%	9.7%	17.6%	14.4%
102	1.5%	1.9%	1.8%	1.6%	2.0%	1.8%
104	13.3%	13.4%	13.3%	11.8%	13.0%	12.5%
107	2.0%	2.3%	2.2%	2.2%	2.6%	2.4%
201	1.0%	1.2%	1.1%	0.7%	0.7%	0.7%
202	25.0%	18.9%	21.4%	20.6%	17.2%	18.6%
207	0.7%	0.3%	0.5%	0.7%	0.4%	0.5%
301	7.7%	3.5%	5.2%	13.0%	6.7%	9.3%
302	2.5%	0.9%	1.6%	7.8%	3.7%	5.3%
303	4.9%	3.8%	4.3%	6.2%	5.8%	5.9%
308	1.2%	1.6%	1.5%	1.4%	1.6%	1.5%
309	0.7%	1.2%	1.0%	0.9%	1.3%	1.1%
406	0.8%	1.0%	0.9%	0.9%	1.1%	1.0%
408	1.4%	1.7%	1.6%	1.1%	1.6%	1.4%
700	0.9%	1.8%	1.4%	0.7%	1.4%	1.1%
703	2.2%	3.6%	3.0%	2.0%	2.8%	2.5%
705	1.3%	1.4%	1.4%	1.2%	1.2%	1.2%
708	1.9%	2.0%	2.0%	1.5%	1.4%	1.5%
803	1.4%	1.6%	1.5%	1.0%	1.2%	1.1%
804	1.7%	0.9%	1.2%	1.3%	0.8%	1.0%
805	1.5%	0.7%	1.0%	0.9%	0.6%	0.7%
808	0.9%	0.6%	0.7%	0.7%	0.4%	0.5%
903	0.1%	0.3%	0.2%	0.1%	0.2%	0.1%
Others	11.0%	10.6%	10.7%	10.1%	10.1%	10.1%
Total crashes	4 603	6 681	11 284	12 553	18 163	30 716

Notes:

1 DCA – Definitions for coding accidents. A chart showing the vehicle movements and descriptions of the DCA codes are provided in Appendix A.

Figure 3.7 shows the intersection injury crashes by DCA code and severity. Though small in numbers, DCA code 903 (hit train) was the most severe, with 70% of crashes resulting in FSI, followed by 004 (playing/working on road) with 60% resulting in FSI, and 201 (head-on) with 56% resulting in FSI.

Figure 3.7: Intersection injury crashes by DCA code and severity (2007–11)



3.6 Intersection Injury Crashes by DCA Code and Traffic Control

Table 3.4 covers intersection injury crashes by DCA code and traffic control type. The main findings are as follows:

- The main crashes at intersections controlled by traffic signals and intersections with no controls were DCA 202.
- About 41% of FSI and 37% of all injury crashes that occurred at intersections controlled by traffic signals were DCA 202.
- The main crashes at intersections controlled by stop or give way signs were DCA 101 and 104.
- 61% of DCA 202 crashes that resulted in FSI occurred at intersections controlled by traffic signals.

Table 3.4: Intersection injury crashes by DCA code and control type (2007–11)

DCA	FSI intersection crashes						All intersection injury crashes					
	No traffic control	Traffic lights	Give way sign	Stop sign	Others	Total	No traffic control	Traffic lights	Give way sign	Stop sign	Others	Total
001	2.2%	4.5%	0.8%	0.8%	24.2%	2.7%	1.5%	3.2%	0.5%	0.6%	18.2%	1.9%
003	2.0%	4.3%	0.3%	0.3%	8.1%	2.3%	1.4%	2.9%	0.2%	0.2%	9.6%	1.5%
004	0.7%	0.3%	0.1%	0.0%	2.0%	0.4%	0.4%	0.2%	0.1%	0.1%	2.1%	0.3%
101	1.9%	12.1%	27.9%	49.0%	3.0%	15.0%	2.0%	10.7%	25.1%	46.5%	2.1%	14.4%
102	0.7%	1.0%	3.7%	3.9%	0.0%	1.8%	0.7%	1.1%	3.4%	4.1%	0.0%	1.8%
104	5.6%	7.6%	27.6%	29.5%	0.0%	13.3%	6.0%	7.4%	22.6%	27.3%	1.0%	12.5%
107	1.3%	0.5%	5.7%	3.0%	0.0%	2.2%	1.3%	0.5%	5.9%	3.2%	0.3%	2.4%
201	2.4%	0.5%	0.3%	0.0%	1.0%	1.1%	1.6%	0.3%	0.2%	0.0%	0.7%	0.7%
202	19.7%	41.0%	4.5%	2.3%	2.0%	21.4%	17.3%	36.6%	4.2%	2.3%	2.1%	18.6%
207	0.5%	0.8%	0.1%	0.0%	0.0%	0.5%	0.8%	0.8%	0.1%	0.0%	0.0%	0.5%
301	4.4%	9.2%	2.3%	0.3%	15.2%	5.2%	7.4%	16.1%	5.4%	1.0%	25.0%	9.3%
302	1.0%	0.4%	4.2%	0.9%	1.0%	1.6%	4.2%	1.6%	11.5%	4.3%	4.1%	5.3%
303	9.6%	1.6%	1.0%	1.3%	0.0%	4.3%	12.5%	3.7%	1.9%	1.5%	0.7%	5.9%
308	2.5%	0.9%	1.0%	0.1%	0.0%	1.5%	2.8%	1.1%	1.0%	0.0%	0.0%	1.5%
309	1.6%	0.9%	0.7%	0.0%	0.0%	1.0%	1.6%	1.1%	1.0%	0.1%	0.0%	1.1%
406	0.9%	0.9%	0.9%	1.0%	0.0%	0.9%	1.3%	0.7%	1.0%	1.2%	0.0%	1.0%
408	2.0%	1.6%	1.1%	0.6%	4.0%	1.6%	2.0%	1.2%	1.0%	0.9%	5.8%	1.4%
700	2.4%	0.4%	1.5%	0.9%	0.0%	1.4%	2.0%	0.4%	1.0%	0.8%	0.7%	1.1%
703	5.9%	1.4%	1.7%	0.5%	2.0%	3.0%	5.0%	1.2%	1.5%	0.5%	1.0%	2.5%
705	1.9%	1.0%	1.4%	0.0%	3.0%	1.4%	1.8%	0.7%	1.1%	0.4%	1.7%	1.2%
708	1.7%	2.1%	2.9%	0.3%	0.0%	2.0%	1.5%	1.6%	1.7%	0.2%	0.0%	1.5%
803	3.7%	0.3%	0.3%	0.1%	1.0%	1.5%	2.8%	0.3%	0.4%	0.0%	0.3%	1.1%
804	3.2%	0.1%	0.3%	0.2%	0.0%	1.2%	2.7%	0.1%	0.3%	0.1%	0.0%	1.0%
805	2.3%	0.2%	0.6%	0.1%	1.0%	1.0%	1.7%	0.1%	0.4%	0.1%	0.7%	0.7%
808	1.2%	0.5%	0.3%	0.0%	1.0%	0.7%	0.9%	0.4%	0.3%	0.0%	0.3%	0.5%
903	0.0%	0.0%	0.3%	0.3%	17.2%	0.2%	0.0%	0.0%	0.1%	0.1%	8.2%	0.1%
Others	18.1%	5.6%	8.6%	4.4%	14.1%	10.7%	17.0%	5.8%	8.1%	4.4%	15.4%	10.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

3.7 Intersection Injury Crashes by Traffic Control Type

Figure 3.8 shows the distribution of intersection crashes by type of traffic control. Overall, intersections with no traffic control recorded the highest number of crashes (33%). On state roads, most of the injury crashes occurred at intersections with traffic lights. On local roads, most of the intersection injury crashes occurred at intersections with no traffic control. Intersections with give way or stop signs also recorded a significant number of injury crashes (27%).

Figure 3.9 shows the intersection injury crashes by traffic control type and severity. The highest proportion of FSI intersection crashes occurred at railway crossings. Intersections controlled by police, pedestrian signals, traffic signals, local area traffic management (LATM), no control, and stop and give way signs also recorded high proportions of FSI intersection injury crashes.

Figure 3.8: Intersection injury crashes by traffic control (2007–11)

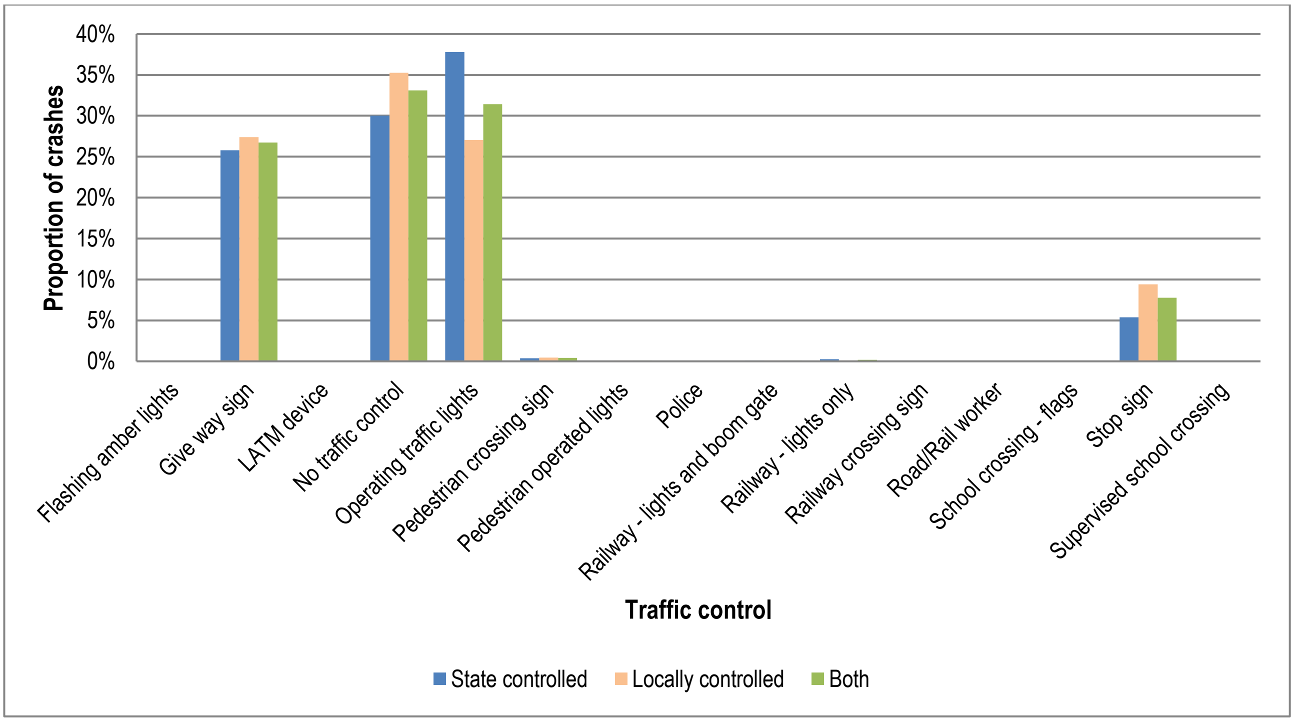
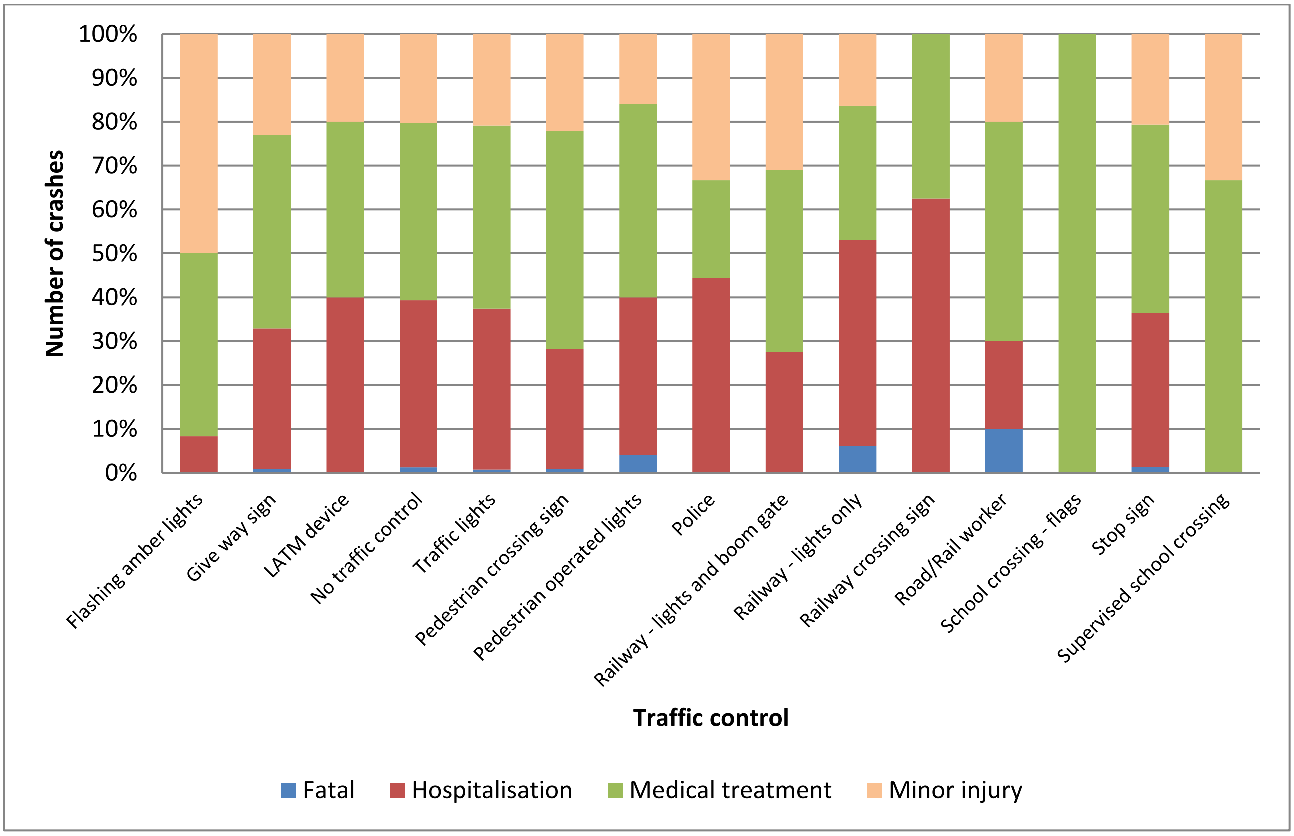


Figure 3.9: Intersection injury crashes by traffic control and severity (2007–11)



3.8 Intersection Injury Crashes by Intersection Type and Traffic Control

Table 3.5 details intersection injury crashes by intersection type and traffic control type. The main findings are as follows:

- At cross-intersections 54% of the injury crashes occurred at intersections controlled by traffic signals.
- At T-junctions most of the crashes occurred with no traffic control (48%), controlled by signals (23%) and give way signs (22%).
- At Y-junctions 42% of the injury crashes occurred where there was no traffic control.
- At interchanges 52% of the injury crashes occurred where there was no traffic control.
- At multiple road intersections 77% of the injury crashes occurred at traffic signal control sites.
- At roundabout 83% of the injury crashes occurred at locations controlled by give way signs.
- At median openings 58% of the injury crashes occurred where there was no traffic control.
- At railway crossings most of the crashes occurred at crossings controlled by lights only (42%), followed by those with lights and a boom gate (24%). This implies that road users are not stopping when the lights turn red.

Table 3.5: Intersection injury crashes by intersection type and traffic control (2007–11)

Intersection type	Give way sign	No traffic control	Operating traffic lights	Stop sign	Railway - lights and boom gate	Railway - lights only	Other	Total
Cross-intersection	2021 (19%)	1293 (12%)	5619 (54%)	1445 (14%)	NA	NA	54 (1%)	**10432 (100%)**
Interchange	261 (14%)	967 (52%)	550 (29%)	85 (5%)	NA	NA	3 (0%)	**1866 (100%)**
Multiple road intersection	8 (7%)	17 (14%)	92 (77%)	2 (2%)	NA	NA	0 (0%)	**119 (100%)**
Roundabout	2636 (83%)	512 (16%)	6 (0%)	1 (0%)	NA	NA	10 (0%)	**3165 (100%)**
T-Junction	3209 (22%)	6980 (48%)	3277 (23%)	826 (6%)	NA	NA	144 (1%)	**14436 (100%)**
Y-Junction	6 (23%)	11 (42%)	5 (19%)	4 (15%)	NA	NA	0 (0%)	**26 (100%)**
Median opening	56 (12%)	265 (58%)	109 (24%)	15 (3%)	NA	NA	8 (2%)	**453 (100%)**
Merge lane	3 (3%)	115 (97%)	0 (0%)	0 (0%)	NA	NA	0 (0%)	**118 (100%)**
Railway crossing	13 (13%)	12 (12%)	0 (0%)	3 (3%)	24 (24%)	42 (42%)	7 (7%)	**101 (100%)**
Total	**8213 (27%)**	**10172 (33%)**	**9658 (31%)**	**2381 (8%)**	**24 (0%)**	**42 (0%)**	**226 (1%)**	**30716 (100%)**

3.9 Intersection Injury Crashes by Posted Speed Limit

Figure 3.10 and Figure 3.11 show the breakdown, by speed zone, of intersection injury crashes and all other crashes respectively. It is noted that:

- There were more intersection injury crashes (89%) on low-speed roads (below 80 km/h) compared to all other injury crashes (61%).

- On state-controlled roads, 22% of crashes occurred on high-speed roads (80 km/h or more) compared to 3% on locally controlled roads.
- Most of the crashes occurred on roads with posted speeds around 60 km/h, on both state and locally controlled roads.

Figure 3.12 shows that the severity of intersection injury crashes generally increased with increased posted speed limit. The figure also highlights that the proportion of fatal intersection crashes increased with the posted speed limit.

Figure 3.10: Intersection injury crashes by posted speed limit (2007–11)

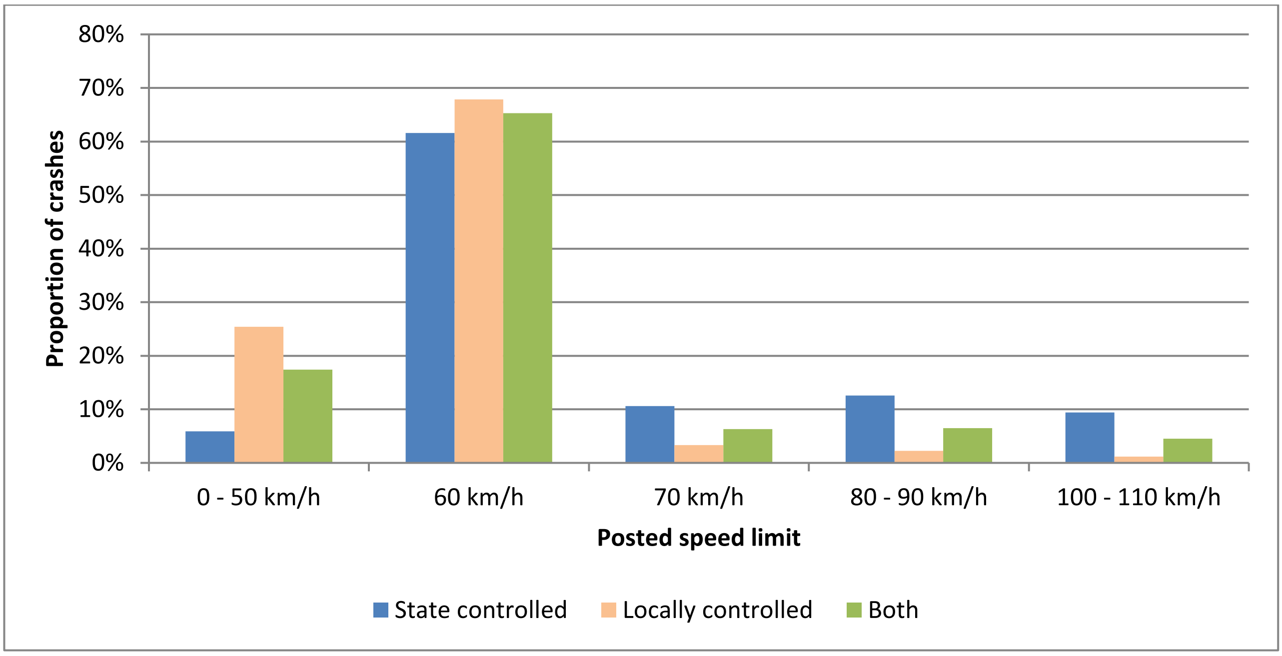


Figure 3.11: All other injury crashes by posted speed limit (2007–11)

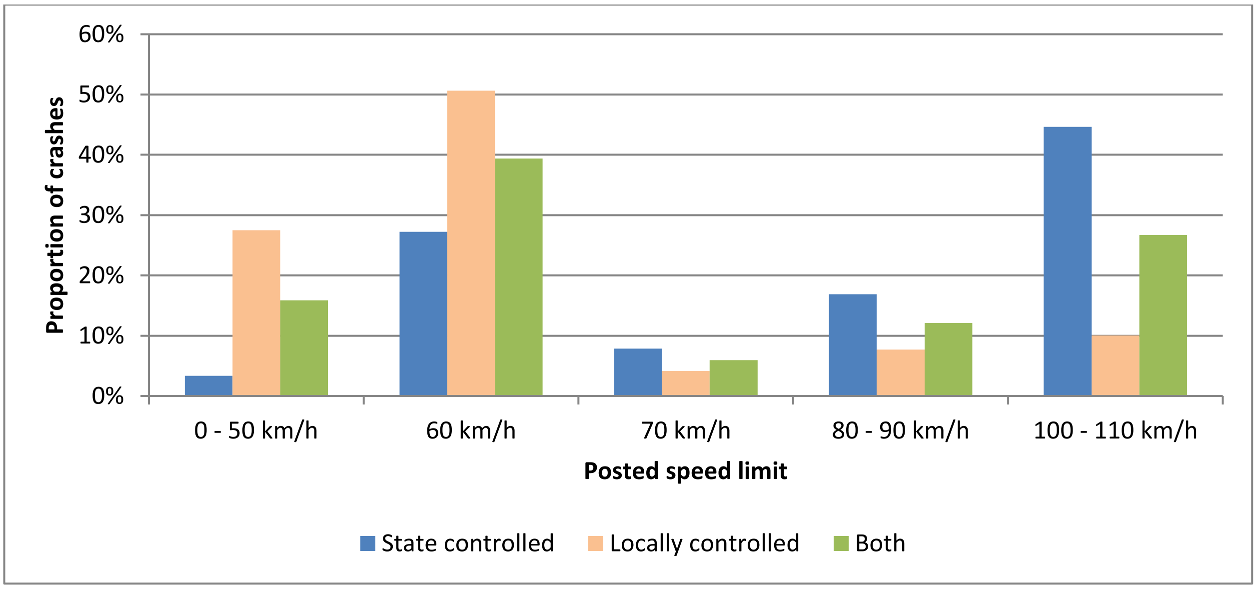
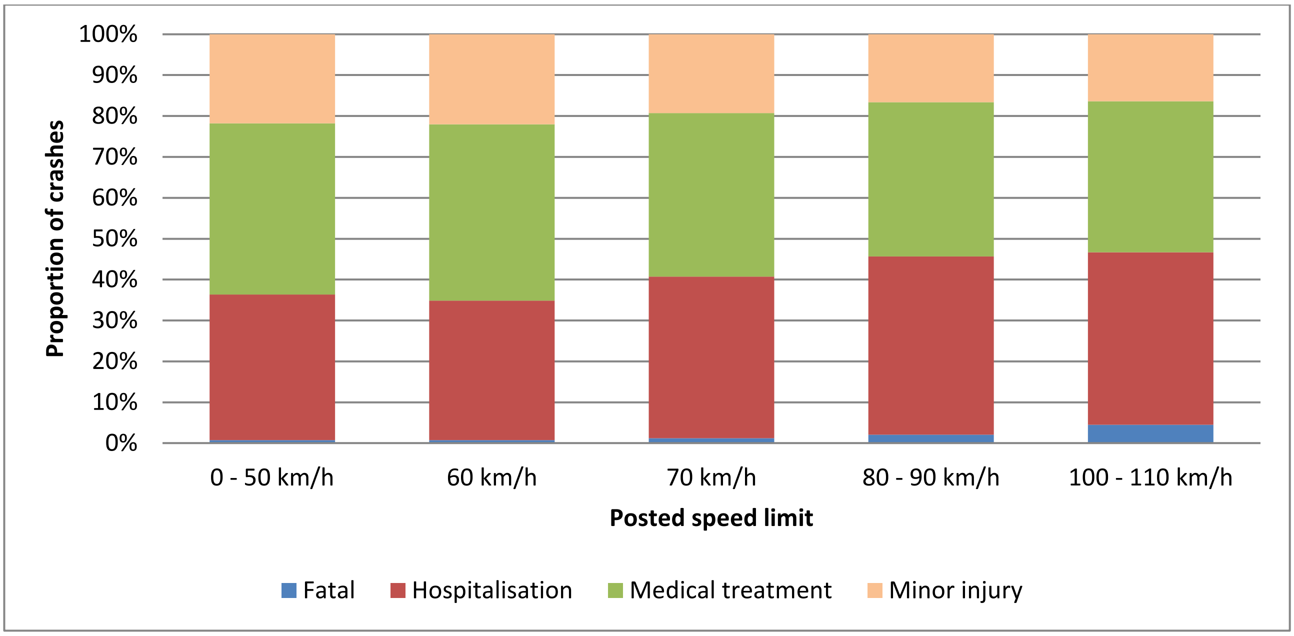


Figure 3.12: Intersection injury crashes by posted speed limit and severity (2007–11)



3.10 Intersection Injury Crashes by Horizontal Alignment

Figure 3.13 shows that 15% of intersection injury crashes occurred on curves (18% on state-controlled roads and 13% on locally controlled roads respectively). This was lower than the 28% for all other injury crashes that occurred on curves (Figure 3.14).

The severity of intersection crashes is the same for both intersections on curves and straight road sections. The proportion of FSI intersection crashes is similar on curves and straight road sections (Figure 3.15).

Figure 3.13: Intersection injury crashes by horizontal alignment (2007–11)

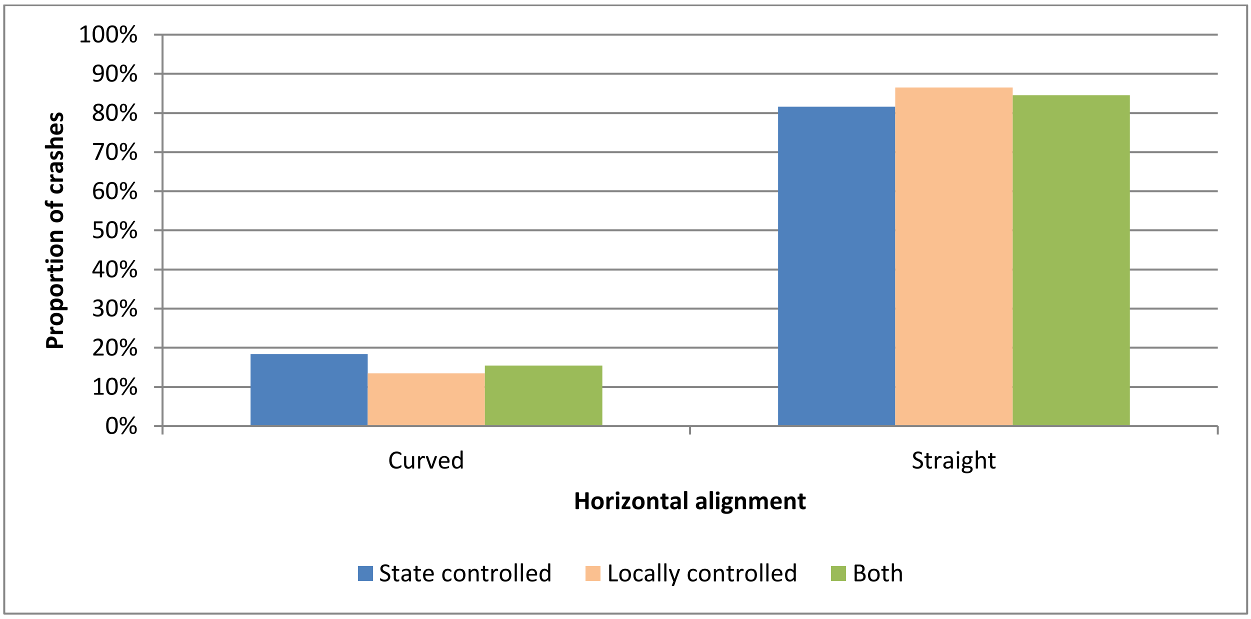


Figure 3.14: All other injury crashes by horizontal alignment (2007–11)

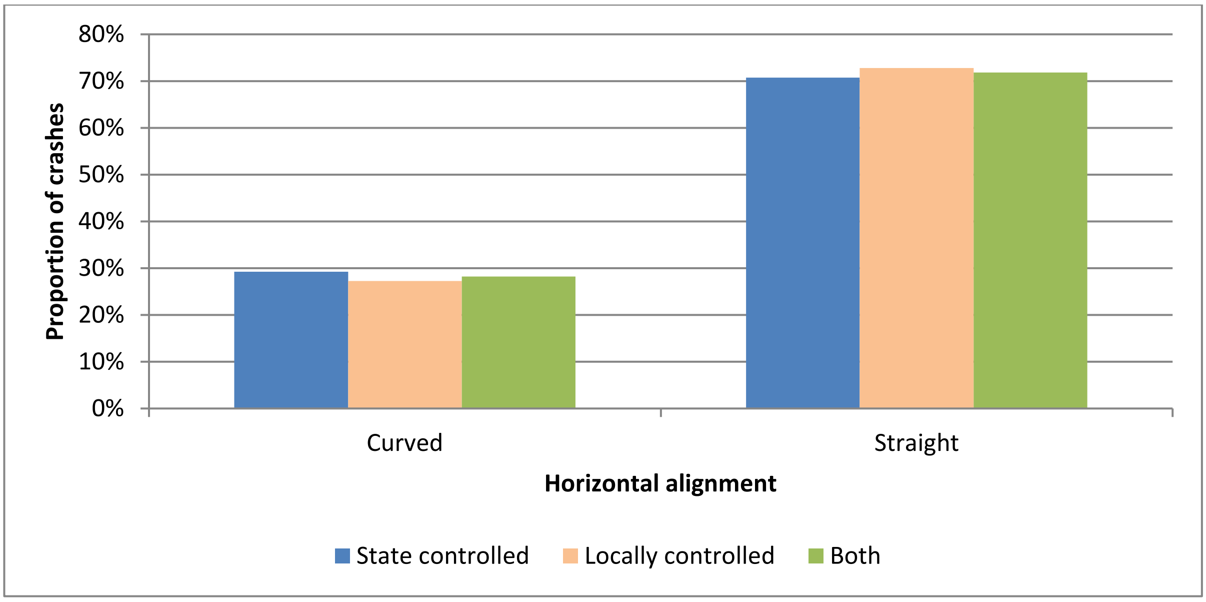
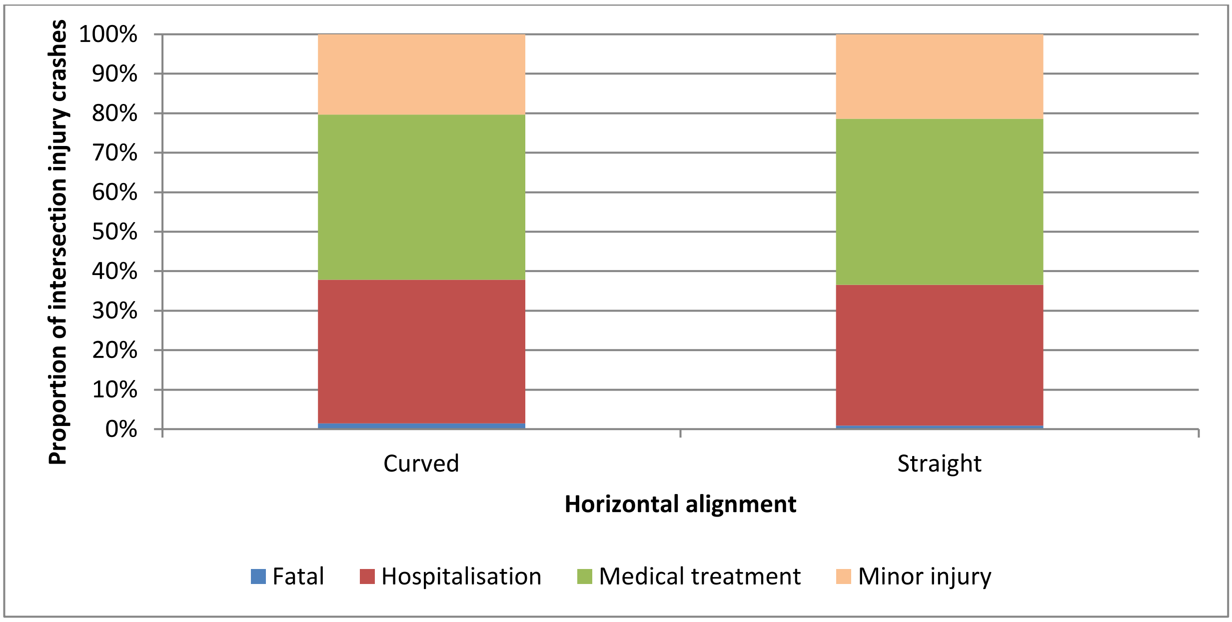


Figure 3.15: Intersection injury crashes by horizontal alignment and severity (2007–11)



3.11 Intersection Injury Crashes by Vertical Alignment

Figure 3.16 shows that 22% of intersection injury crashes occurred on a grade, dip or crest. This was lower than the 28% for all other injury crashes on Queensland roads that occurred on a grade, dip or crest (Figure 3.17). Crests and dips accounted for 7% of intersection injury crashes on state-controlled roads and 9% on locally controlled roads.

Figure 3.18 shows that the proportion of FSI crashes was highest on intersections on dips. Overall, the severity of crashes was slightly higher on upwards and downwards slopes than on level road.

Figure 3.16: Intersection injury crashes by vertical alignment (2007–11)

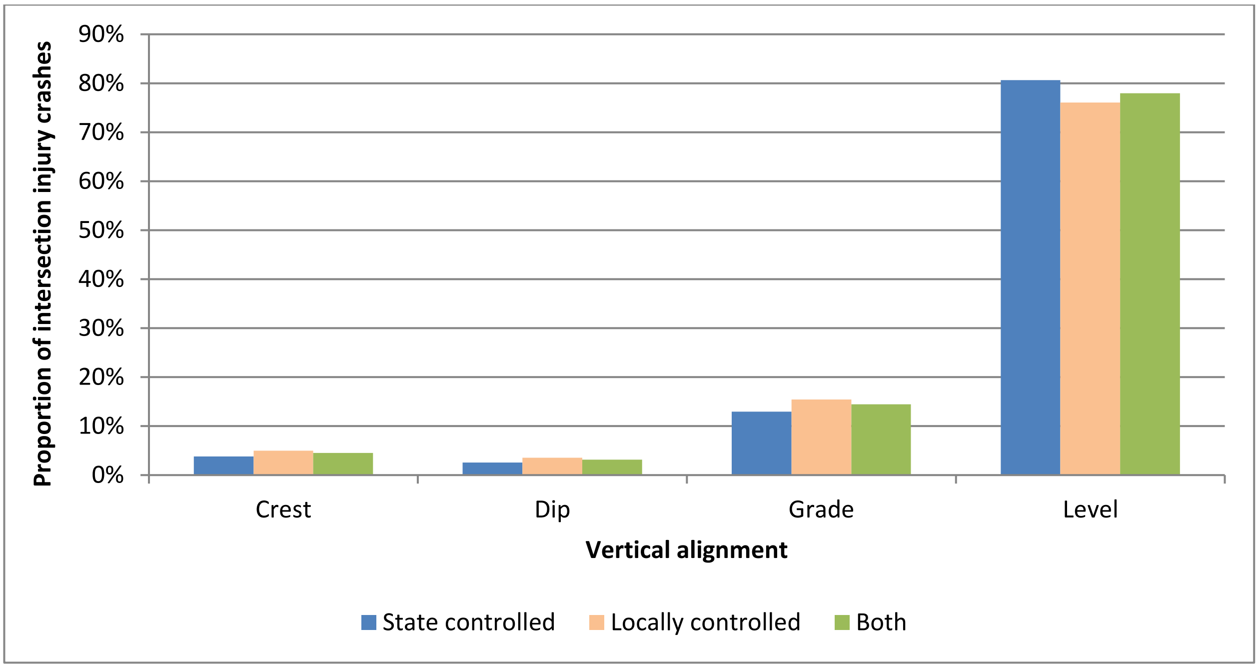


Figure 3.17: All other injury crashes by vertical alignment (2007–11)

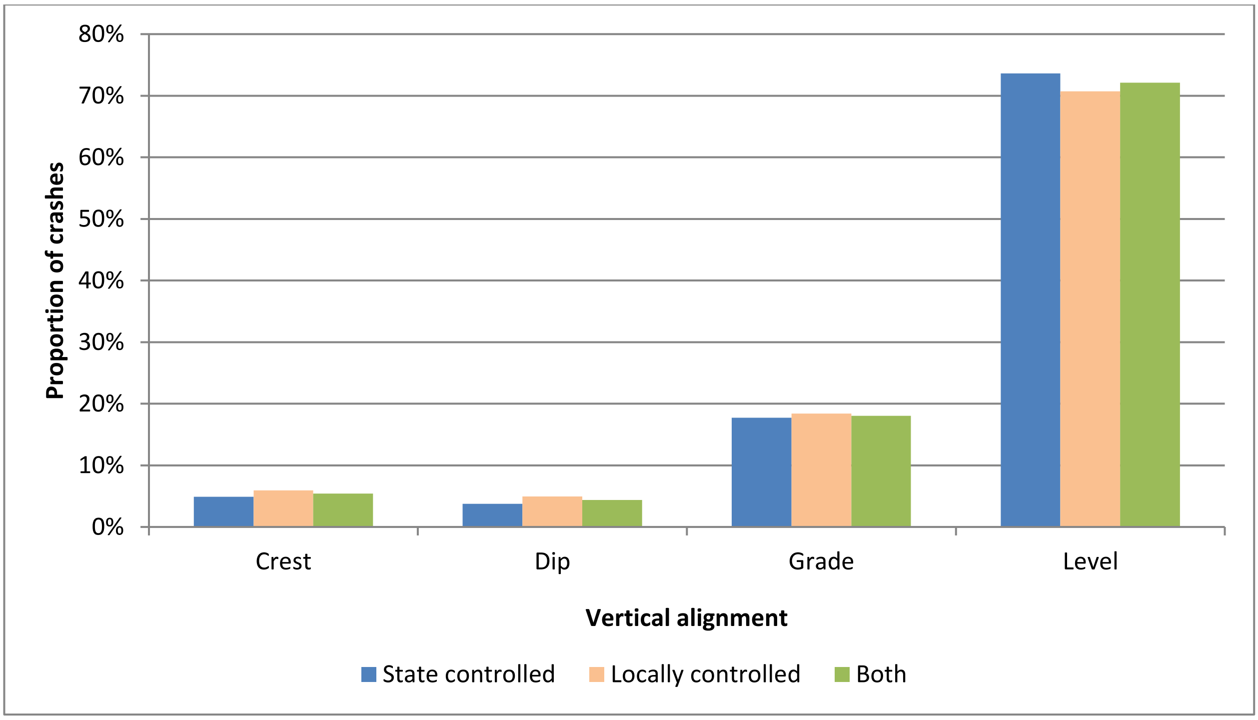
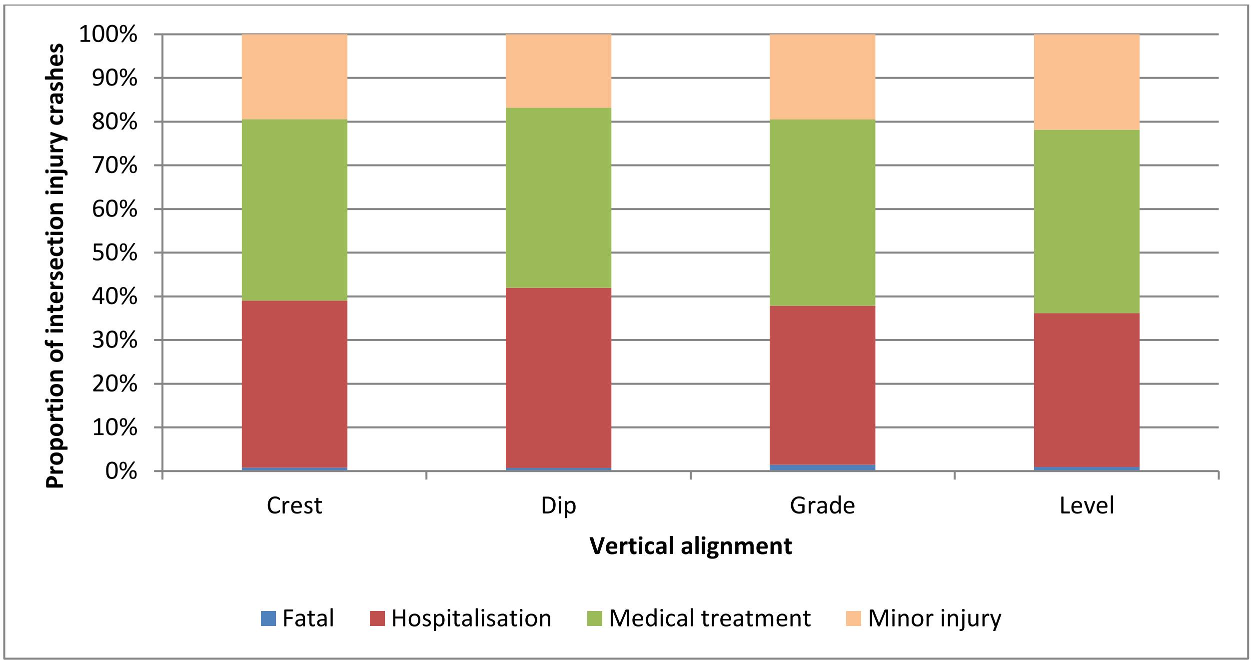


Figure 3.18: Intersection injury crashes by vertical alignment and severity (2007–11)



3.12 Intersection Injury Crashes by Road Surface Condition

Figure 3.19 shows the proportion of intersection injury crashes by road surface condition. About 85% of intersection injury crashes occurred on a dry sealed road surface, higher than the 31% for all other injury crashes (Figure 3.20). About 15% occurred on wet sealed road surfaces. Unsealed sections (both dry and wet) accounted for 1% of the intersection injury crashes on state-controlled and locally controlled roads.

Figure 3.21 shows that unsealed intersections are less safe. The proportion of fatal and FSI crashes is higher on dry unsealed intersections than on sealed intersections.

Figure 3.19: Intersection injury crashes by road surface condition (2007–11)

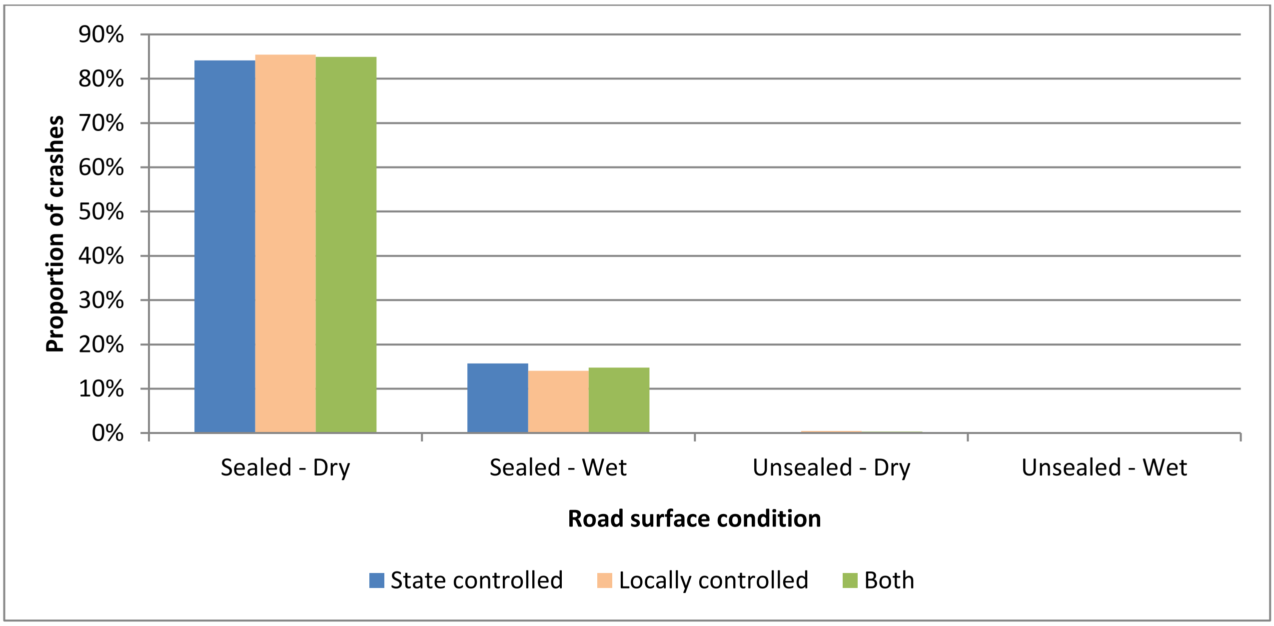


Figure 3.20: All other injury crashes by road surface condition (2007-11)

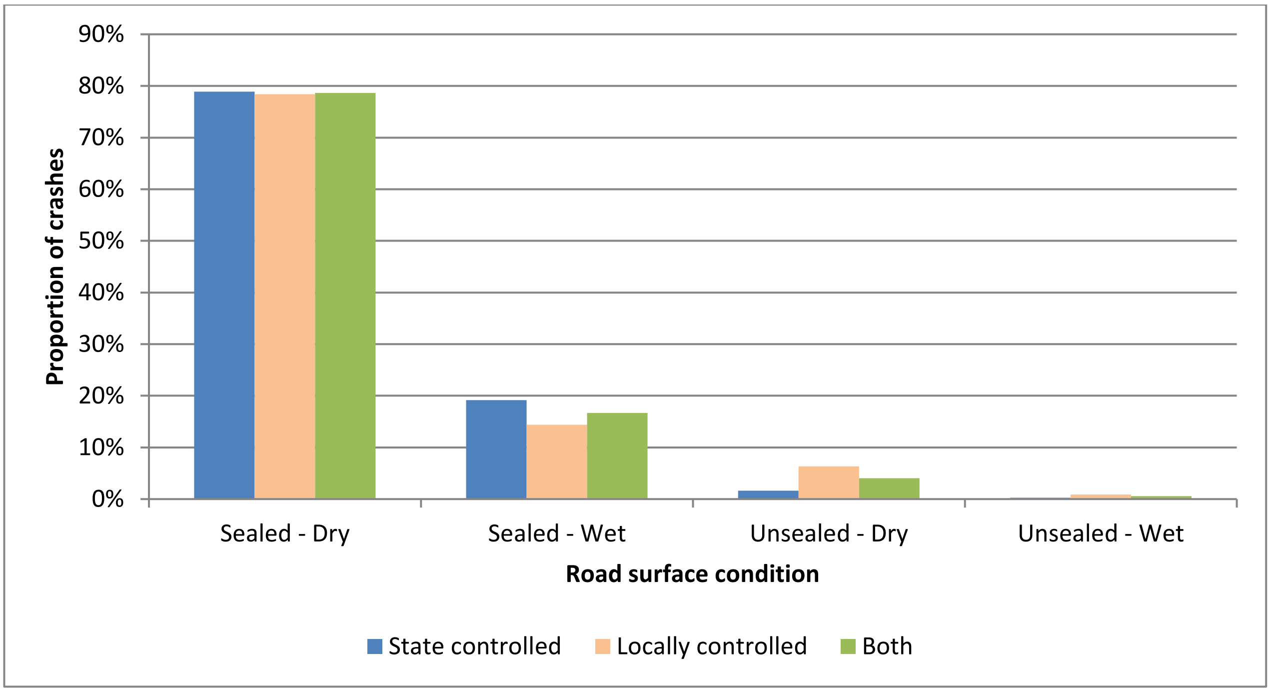
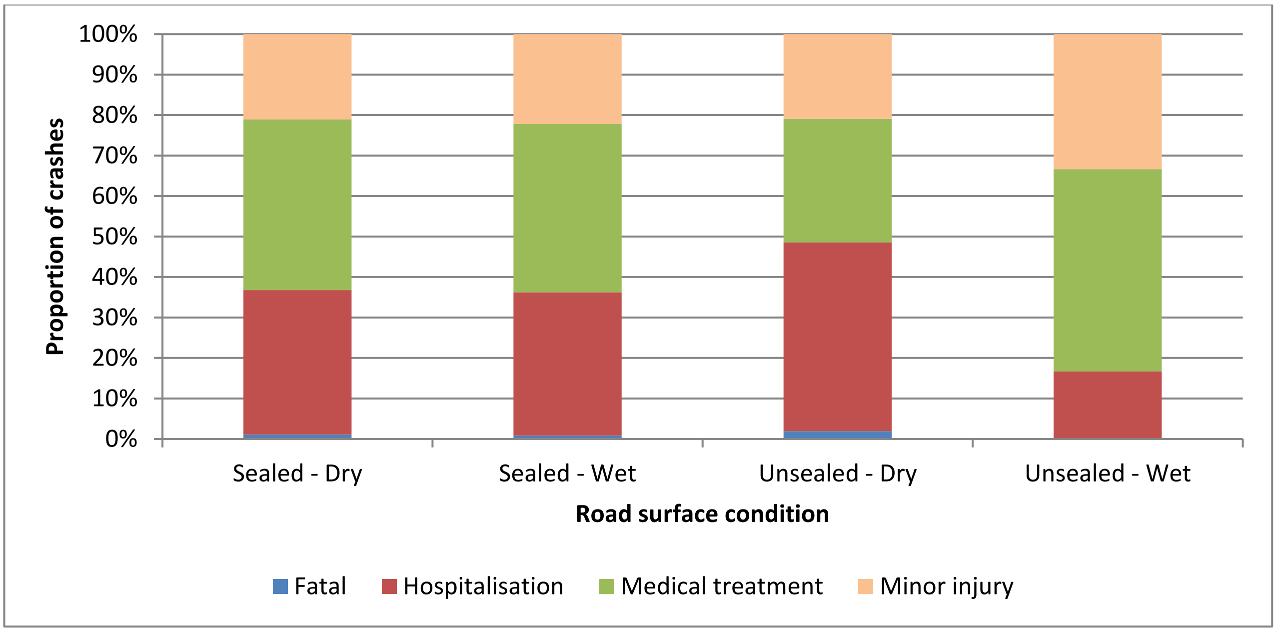


Figure 3.21: Intersection injury crashes by road surface condition and severity (2007–11)



3.13 Intersection Injury Crashes by Lighting Condition

Figure 3.22 shows the proportion of intersection injury crashes by lighting conditions. About 28% of intersection injury crashes occurred during adverse lighting conditions (i.e. dark and dusk/dawn) on Queensland roads. This proportion is marginally lower than the 31% for all other injury crashes (Figure 3.23).

Crashes at unlit intersections are more severe than under other lighting conditions. Unlit intersections recorded the highest proportion of FSI and fatal night-time crashes (Figure 3.24). Daylight had the lowest proportion of FSI crashes.

Figure 3.22: Intersection injury crashes by lighting condition (2007–11)

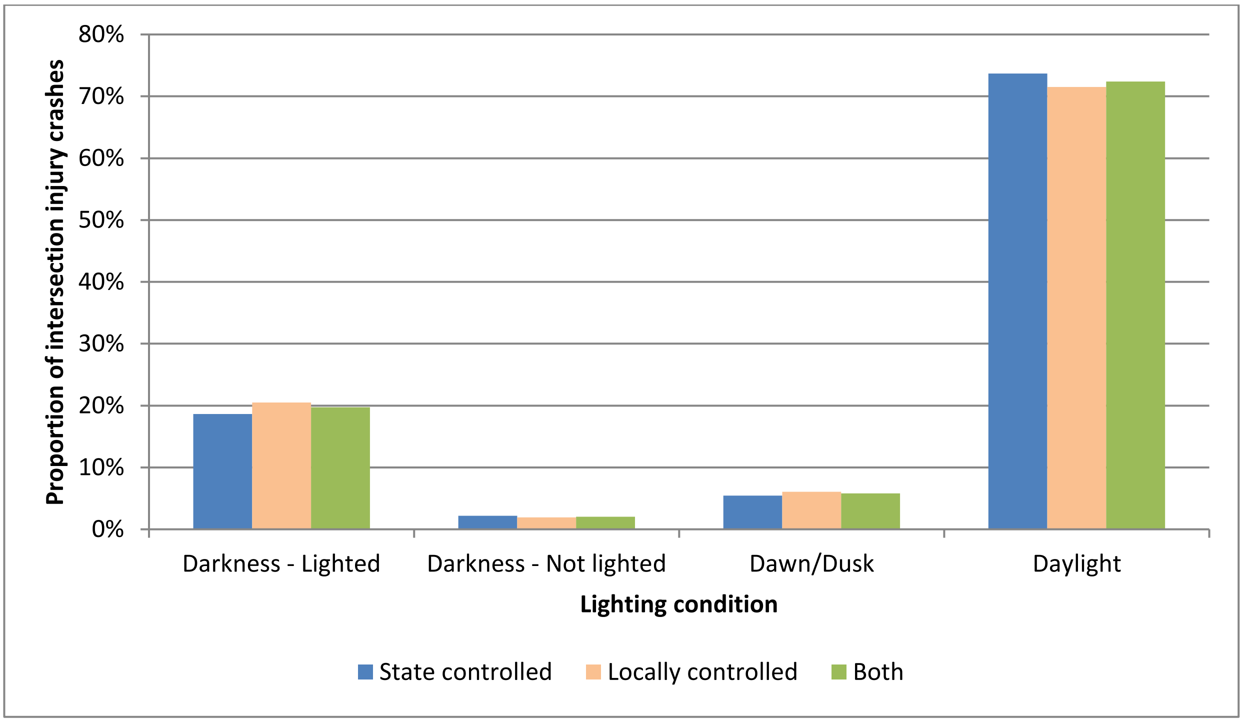


Figure 3.23: All other injury crashes by lighting condition (2007–11)

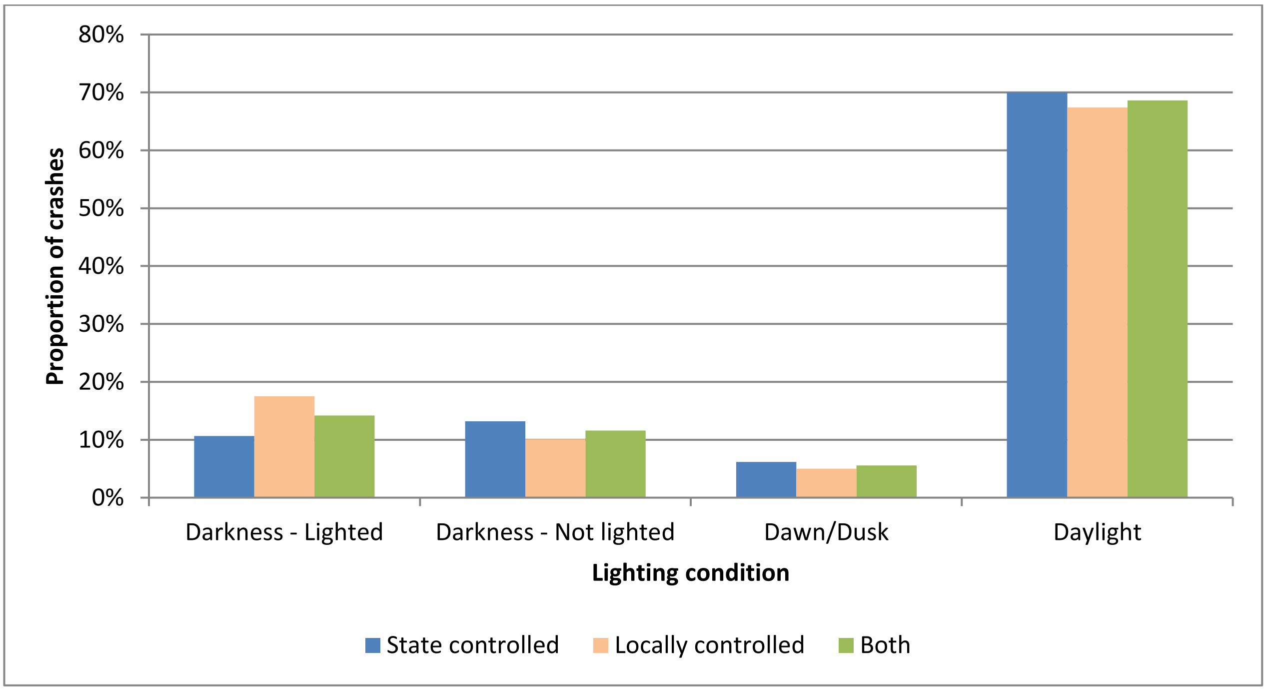
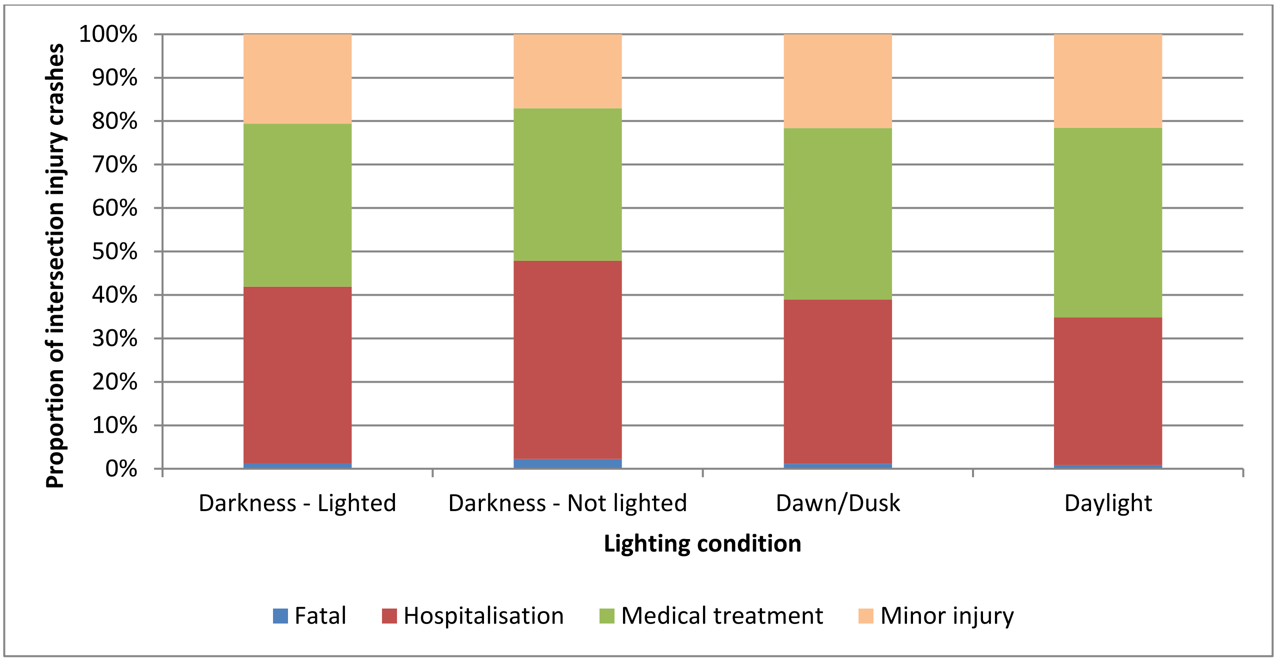


Figure 3.24: Intersection injury crashes by lighting condition and severity (2007–11)



3.14 Intersection Injury Crashes by Time of Day

Figure 3.25 shows that intersection crashes peaked around 3 pm, followed by a decline with the lowest crash numbers between midnight and 4 am. The proportions of crashes during the morning peak (7–9 am) and evening peak (3–6 pm) were 18% and 31% respectively. The corresponding proportions for all other injury crashes during the morning peak (7–9 am) and evening peak (3–6 pm) were 17% and 29% respectively (Figure 3.26). Thus, the proportion of intersection injury crashes during the peak periods was higher compared to all other injury crashes.

Figure 3.25: Intersection injury crashes by time of day (2007–11)

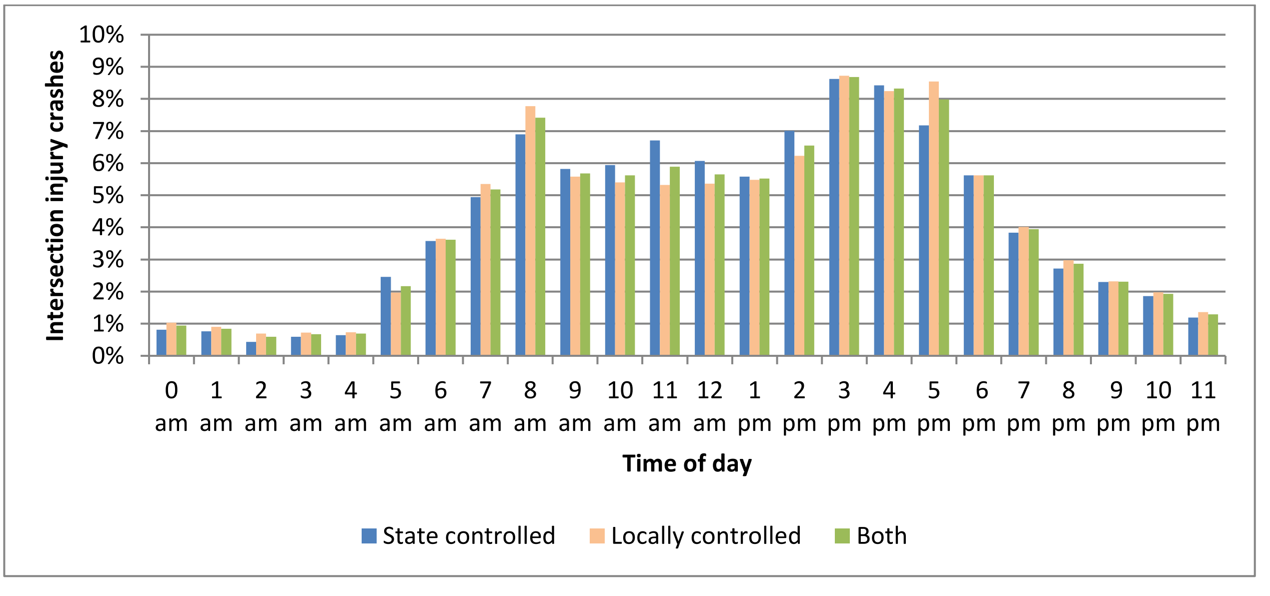
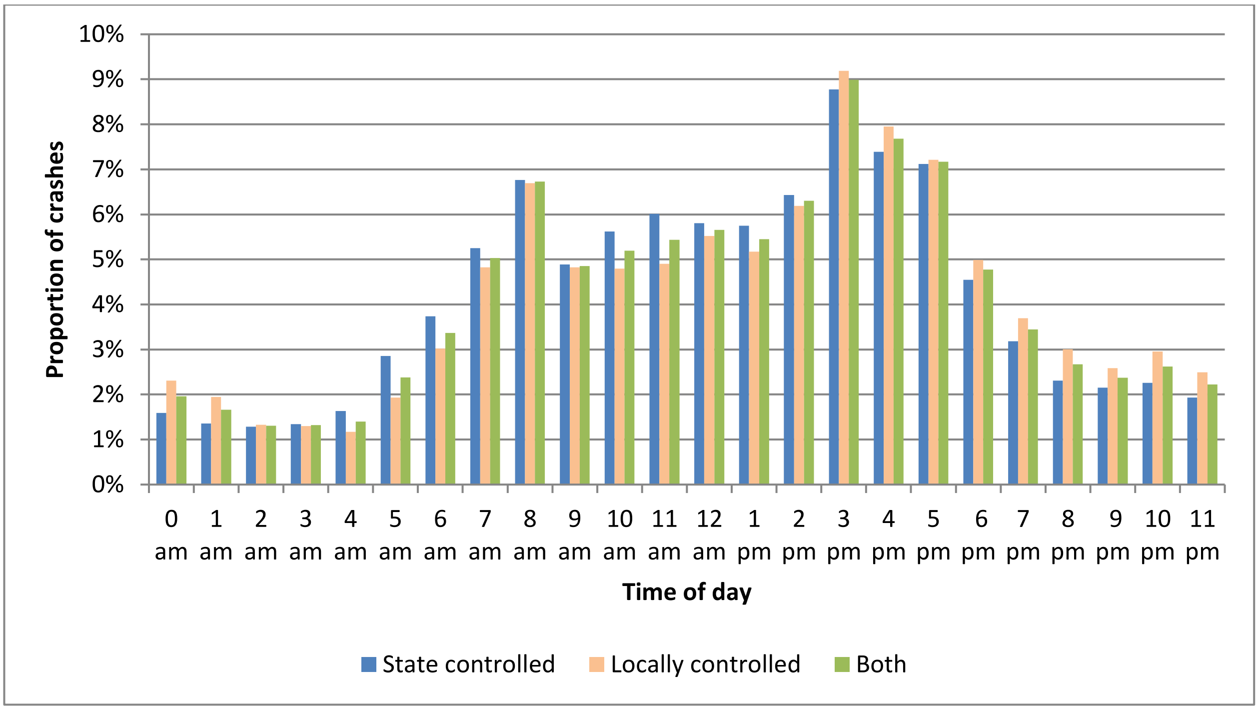


Figure 3.26: All other injury crashes by time of day (2007–11)



3.15 Intersection Injury Crashes by Day of Week

Figure 3.27 shows the weekly pattern of intersection injury crashes. On both state and locally controlled roads, Friday was the peak for intersection crashes. During the week, intersection injury crashes steadily increased from Monday until Friday, then dropped off on the weekend.

All other injury crashes also peaked on Friday (Figure 3.28). The distribution of all other injury crashes throughout the week is similar to that of intersection crashes.

Figure 3.27: Intersection injury crashes by day of week (2007–11)

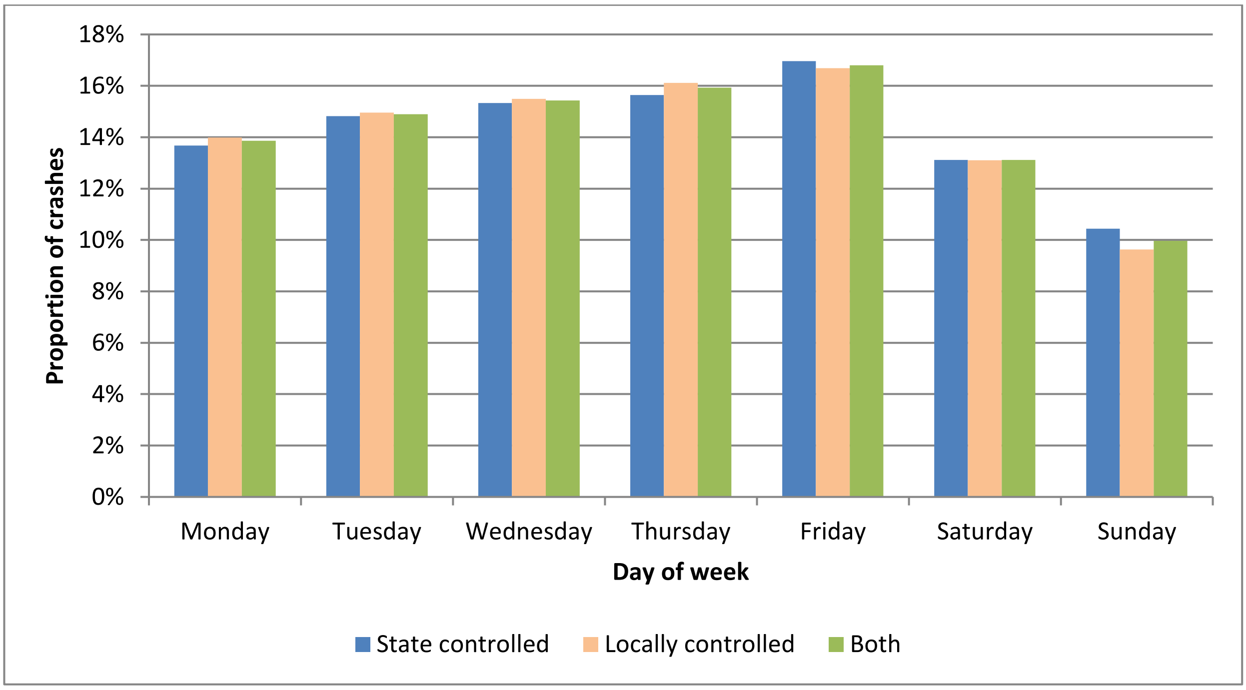
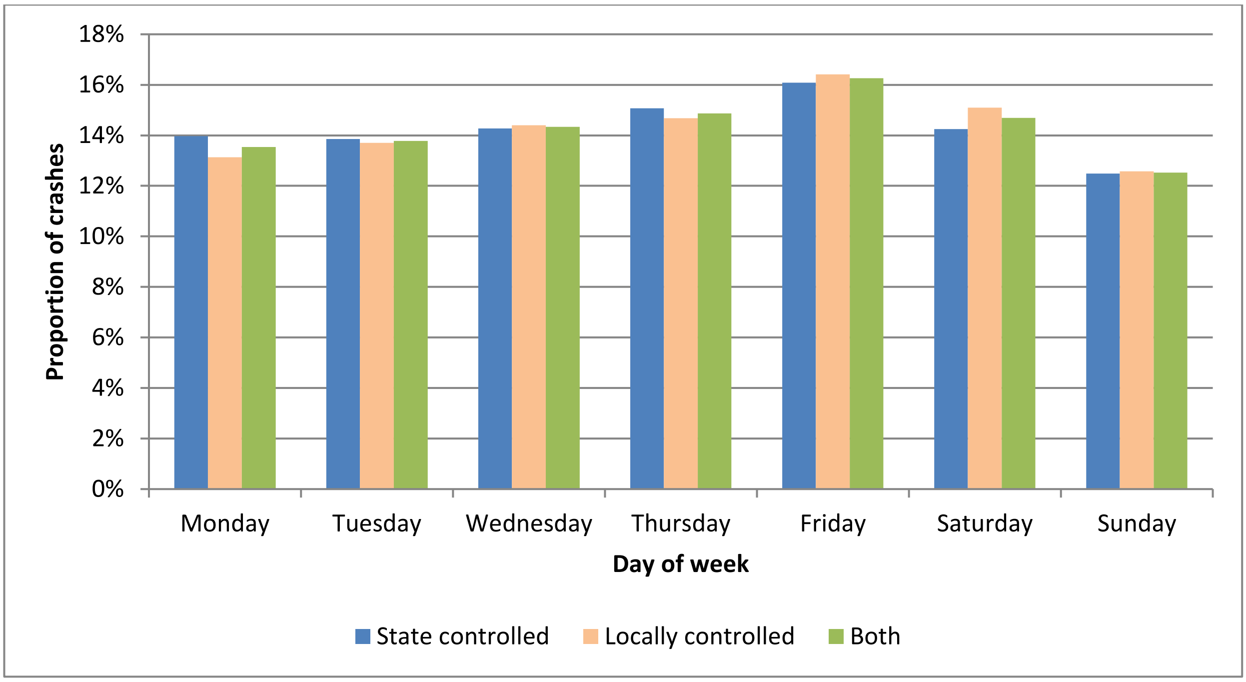


Figure 3.28: All other injury crashes by day of week (2007–11)



3.16 Intersection Injury Crashes by Crash Factors

Figure 3.29 shows the breakdown of contributing crash factors in intersection injury crashes. Drivers disobeying the road rules is the most frequently recorded factor (79%), followed by young adult drivers between 16 and 24 years old (38%), senior adult drivers 60 years old or more (23%), controller condition (11%) and alcohol related crashes (8%).

These five contributory factors are the same factors for all other injury crashes in Queensland during the same period (Figure 3.31).

Figure 3.29: Intersection injury crashes by crash factor (2007–11)

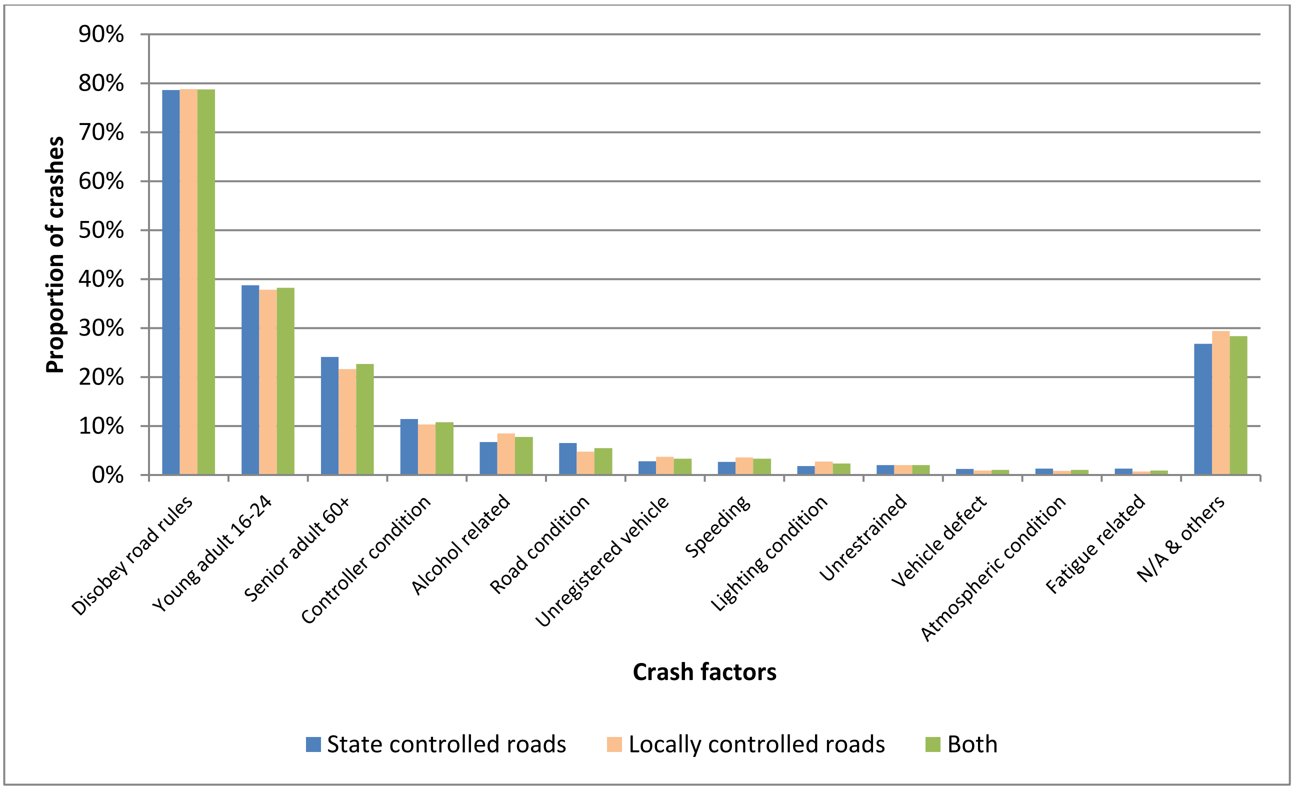
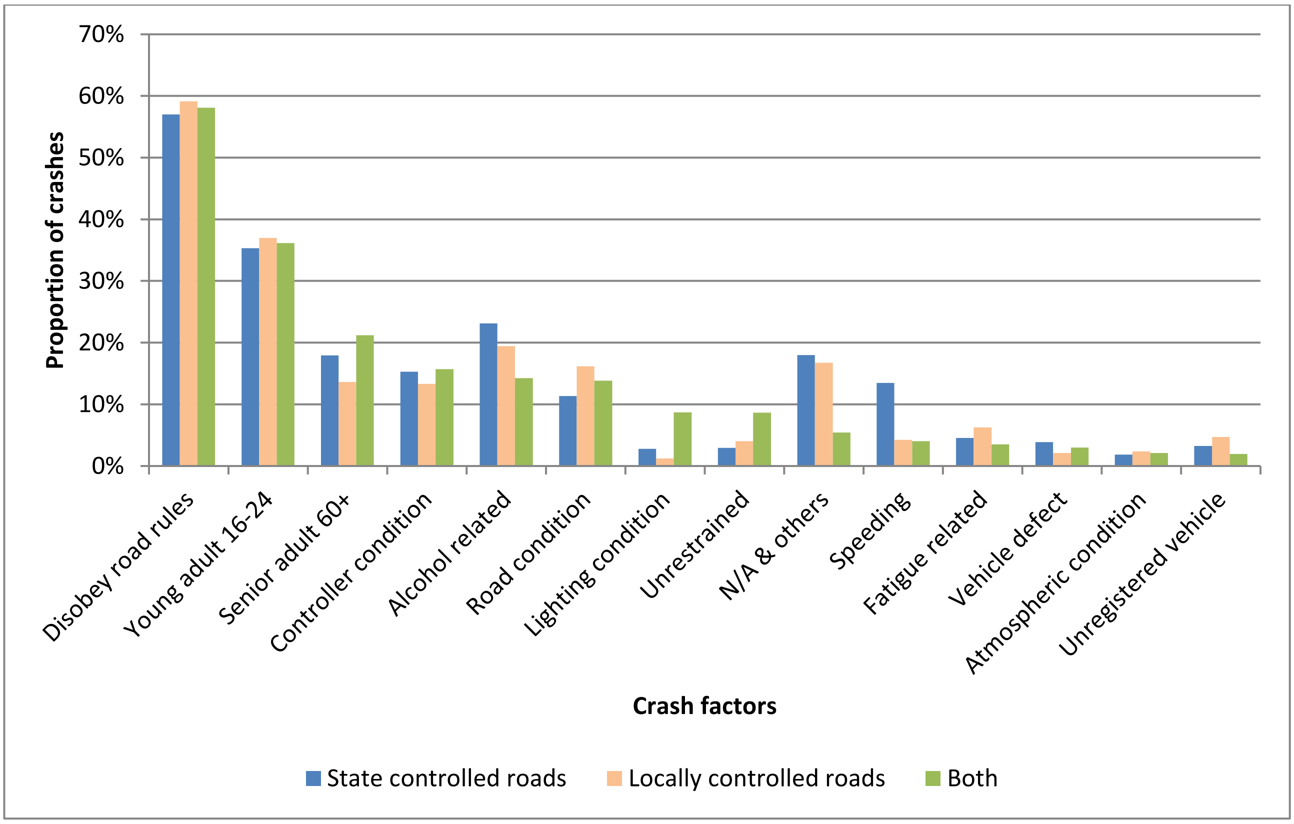


Figure 3.30: All other injury crashes by crash factor (2007-11)



3.17 Intersection Injury Crashes by Primary Vehicle Controller Age

Figure 3.31 shows the age groups of the primary vehicle controller (vehicle unit 1) involved in intersection injury crashes. Middle-aged controllers 25 to 59 years old accounted for the highest proportion of intersection injury crashes (60%) followed by young adult drivers aged 16 to 24 (23%), and then those aged 60 to 74 years (10%).

The proportion of middle-aged drivers (60%) involved in intersection injury crashes was marginally higher than those involved in all other injury crashes (59%) (Figure 3.32).

The proportions of crashes for all age groups on state and locally controlled roads were relatively similar.

Figure 3.33 shows the intersection injury crashes by controller age group and severity. In terms of FSI crashes, the most vulnerable age groups, children 0–15 years (mostly cyclists) and people aged 60 years and over are most at risk.

Figure 3.31: Intersection injury crashes by age group of the primary vehicle controller (2007–11)

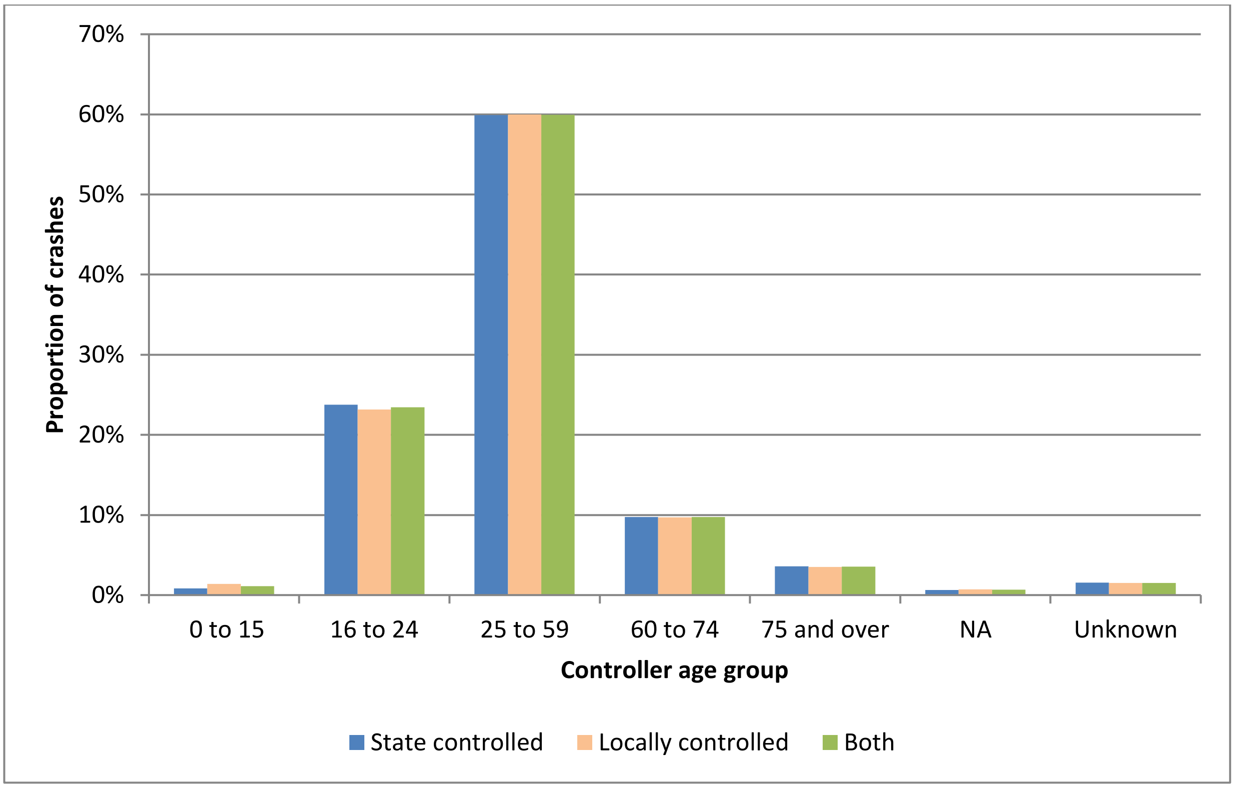


Figure 3.32: All other injury crashes by age group of the primary vehicle controller (2007–11)

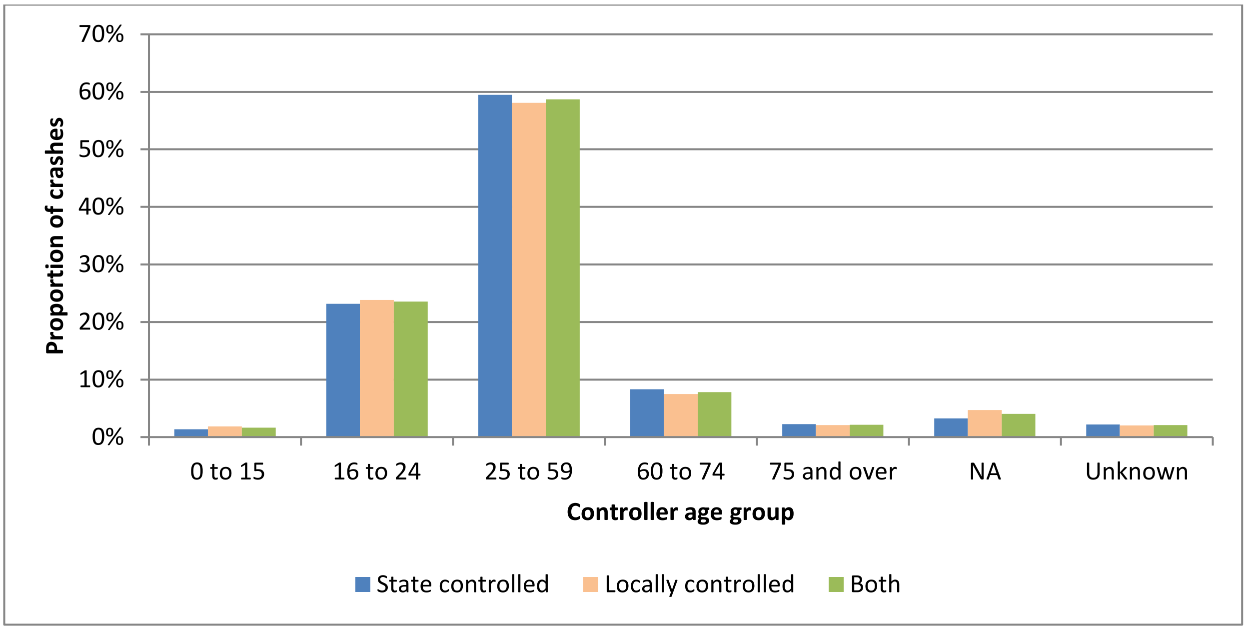
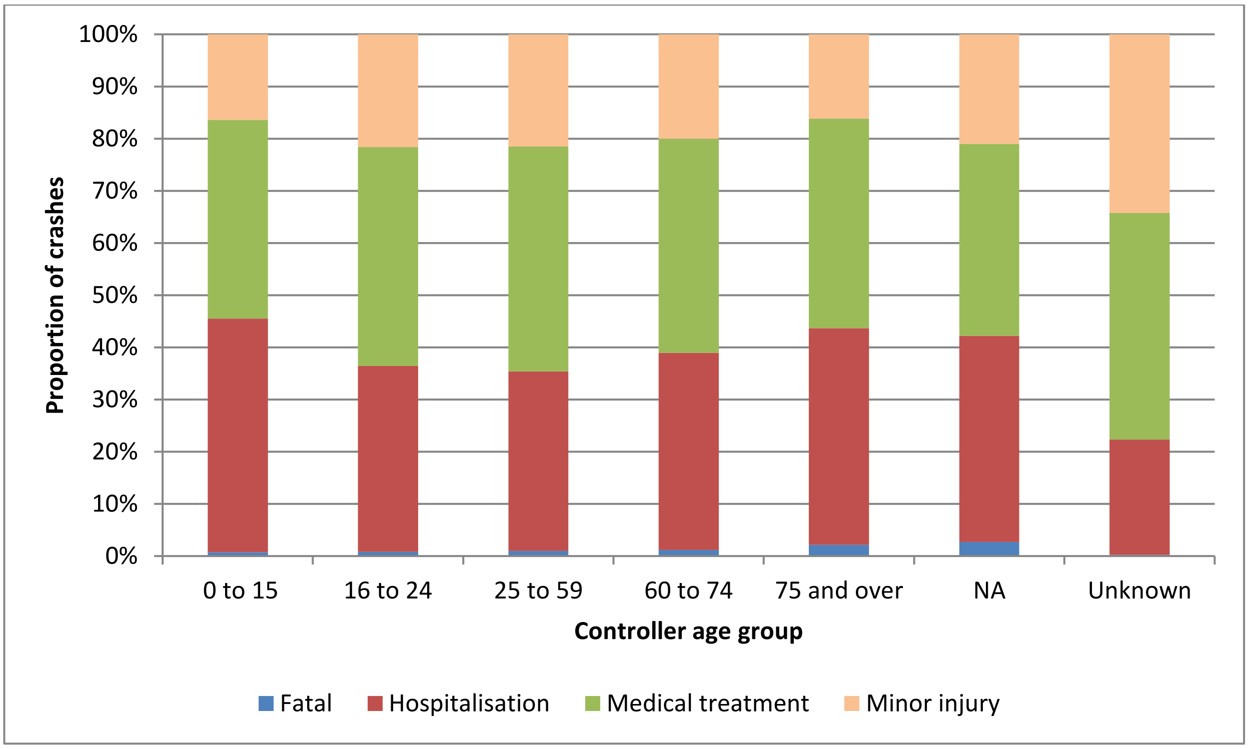


Figure 3.33: Intersection injury crashes by primary vehicle controller age and severity (2007–11)



3.18 Intersection Injury Crashes by Primary Vehicle Controller Gender

Figure 3.34 shows that male controllers of the primary vehicle accounted for 59% of the intersection injury crashes, which is lower than those involved in other injury crashes (64%) (Figure 3.35). The pattern was the same for both state and locally controlled roads.

Figure 3.36 shows that the proportions of FSI crashes at intersections were slightly higher for male controllers (38%) than female controllers (34%).

Figure 3.34: Intersection injury crashes by gender of the primary vehicle controller (2007–11)

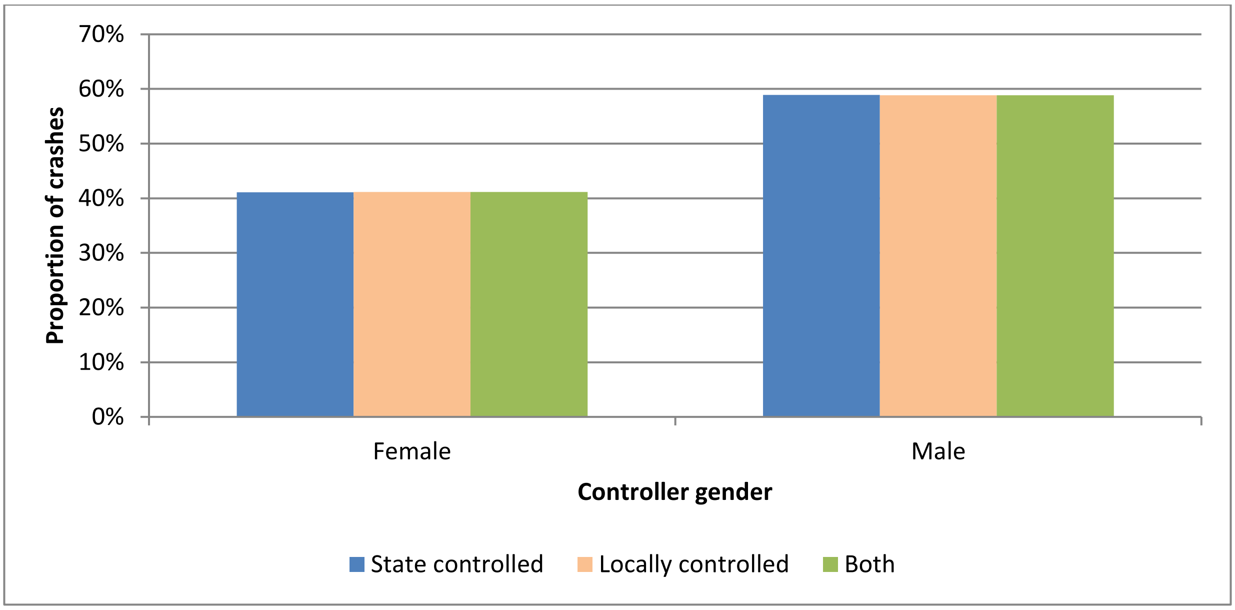


Figure 3.35: All other injury crashes by gender of the primary vehicle controller (2007–11)

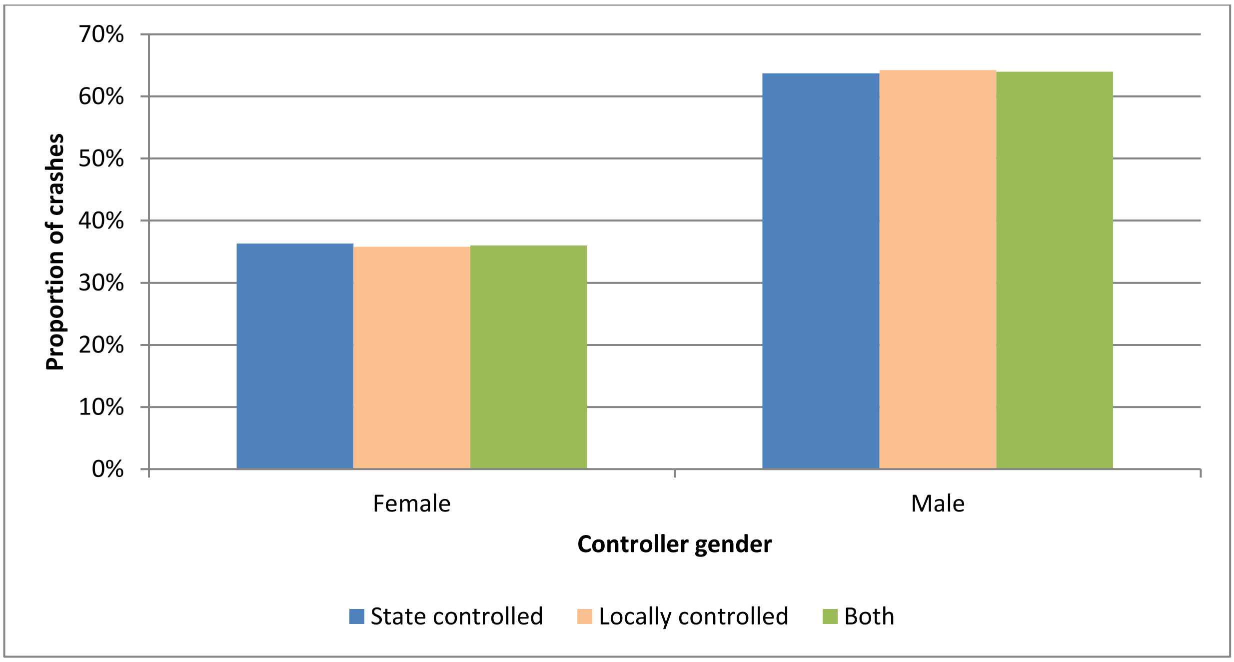
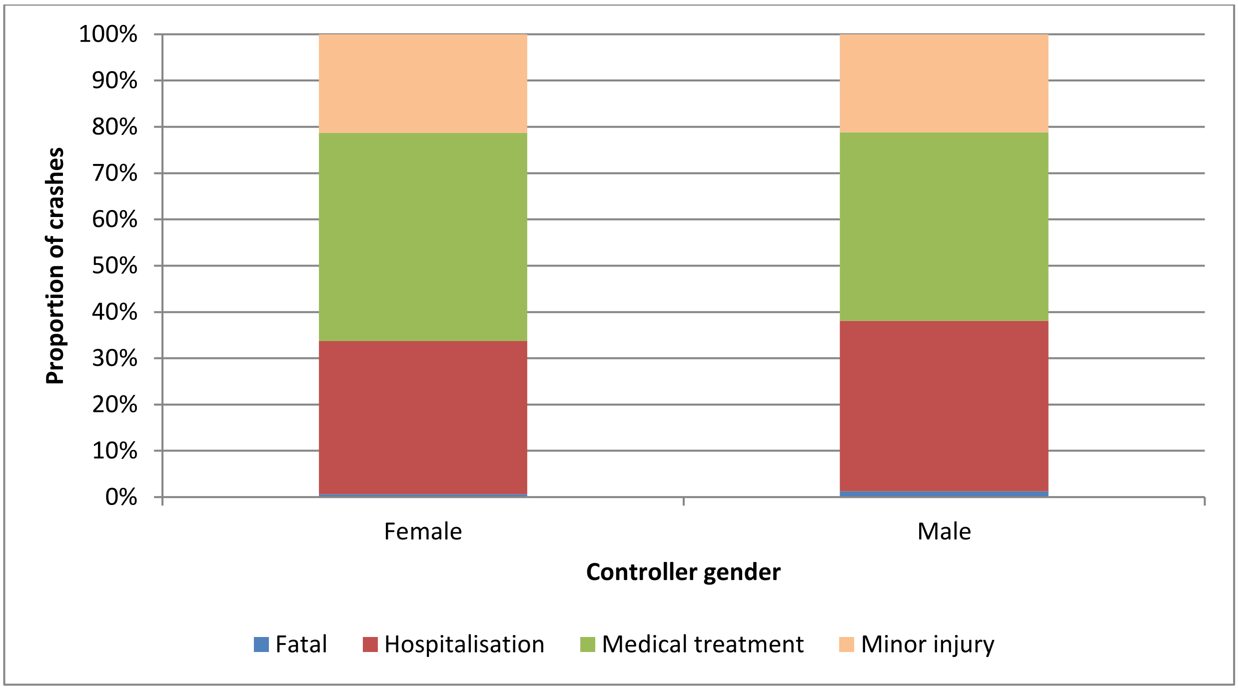


Figure 3.36: Severity of intersection injury crashes by gender of the primary vehicle controller (2007–11)



3.19 Intersection Injury Crashes by Primary Vehicle Age

Figure 3.37 illustrates the age of the primary vehicles involved in intersection injury crashes. The proportion of crashes peaked for vehicles 3 years of age, followed by a gradual decline in crash numbers for older vehicles. The distribution is similar for all other injury crashes (Figure 3.38).

The age of the primary vehicle does not have any distinct effect on the severity of the intersection injury crashes (Figure 3.39). This implies that vehicle safety features in newer vehicles do not provide added protection against the severity outcomes of intersection crashes.

Figure 3.37: Intersection injury crashes by primary vehicle age (2007–11)

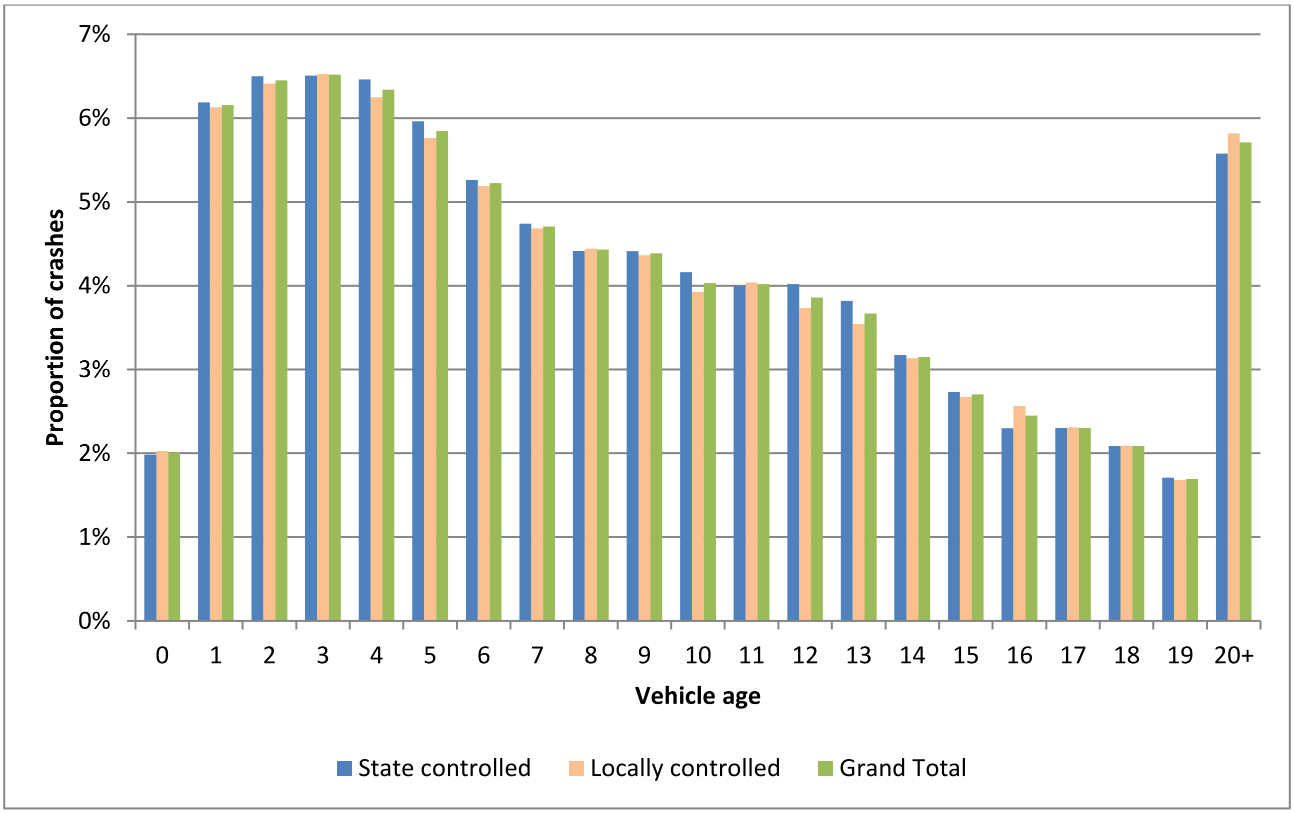


Figure 3.38: All other injury crashes by primary vehicle age (2007–11)

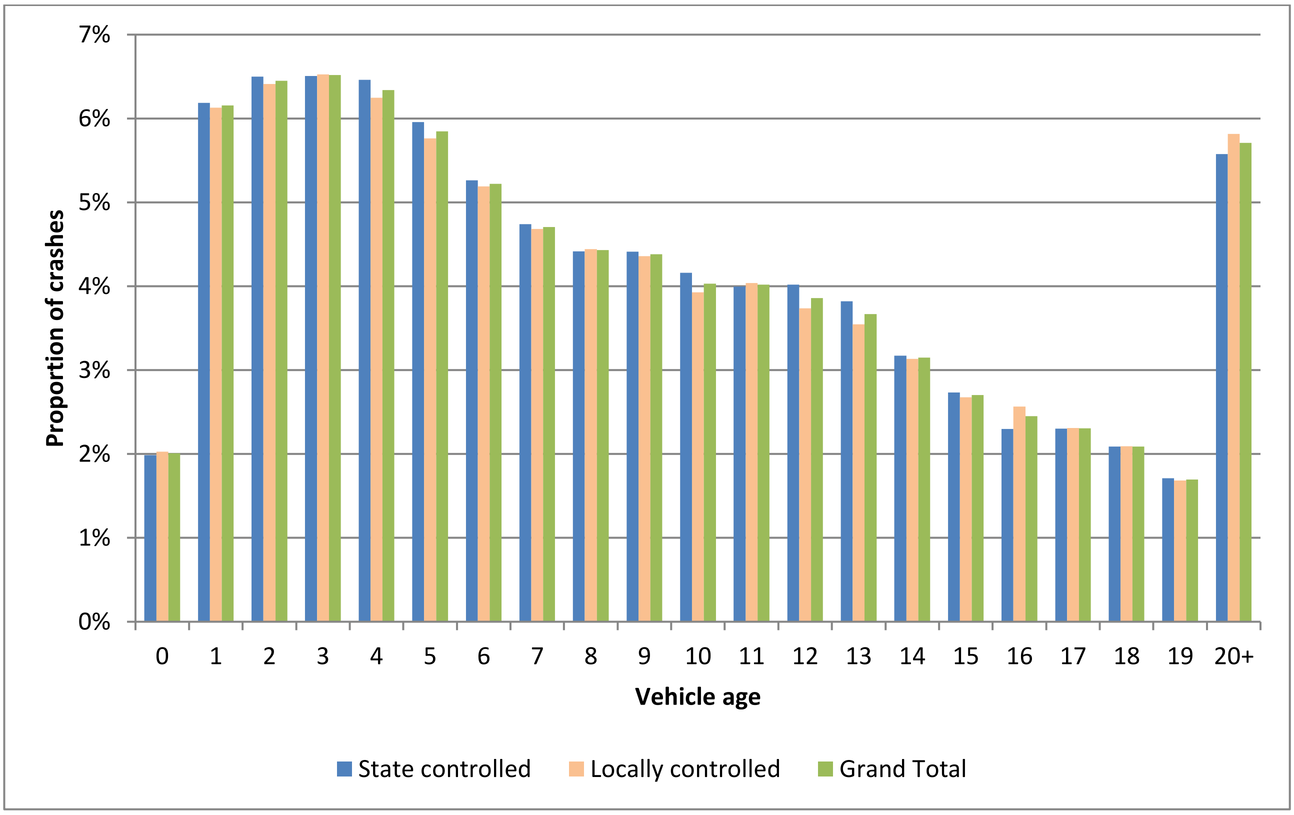
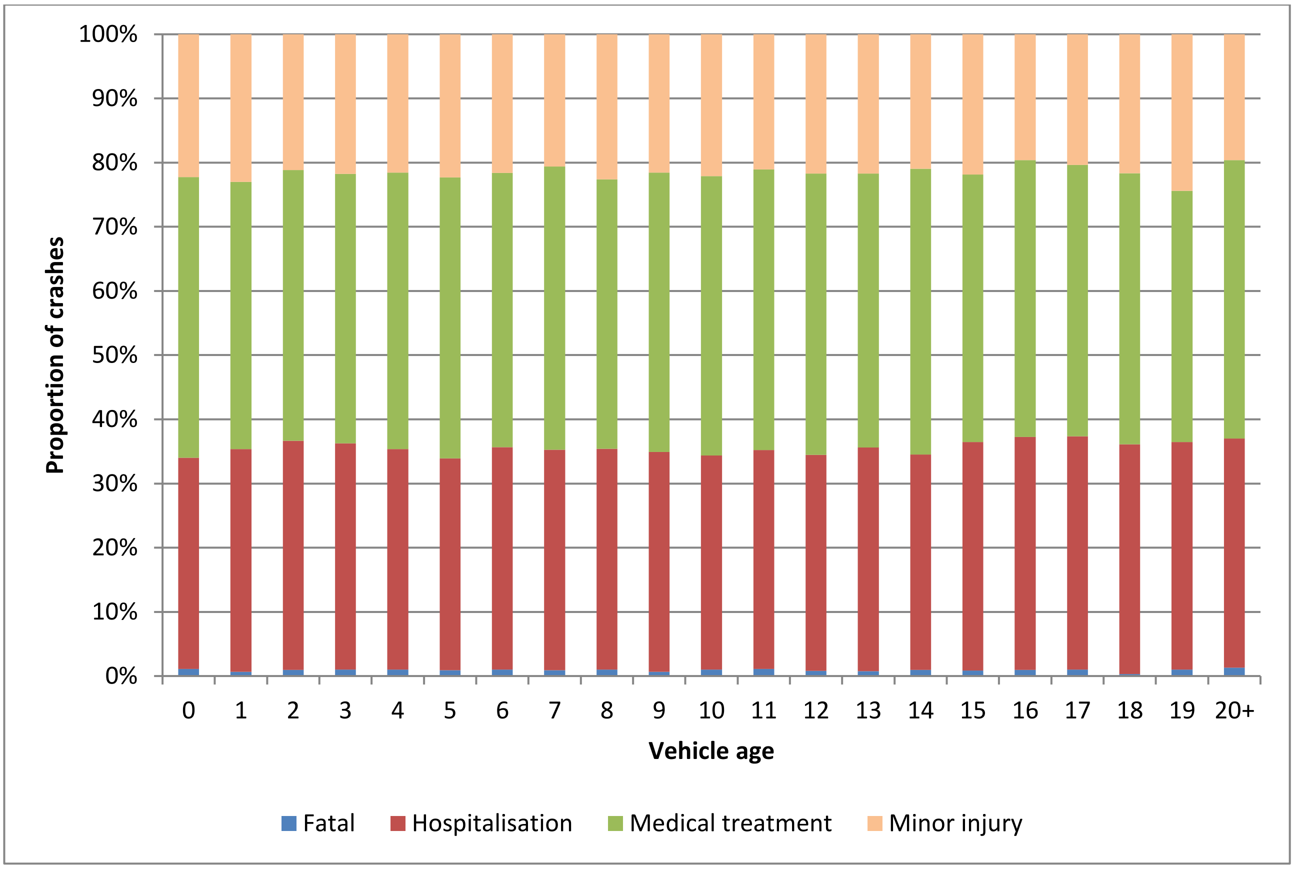


Figure 3.39: Intersection injury crashes by primary vehicle age and severity (2007–11)



3.20 Intersection Injury Crashes by Primary Vehicle Type

Figure 3.40 to Figure 3.42 show the different vehicle units by primary vehicle involved in intersection and all other crashes. Notable findings include:

- Light passenger vehicles were involved in 84% (Figure 3.40) of intersection injury crashes compared to 82% for all other injury crashes (Figure 3.41).
- Motorcycles/mopeds were involved in 6% (Figure 3.40) of intersection injury crashes compared to 7% for all other injury crashes (Figure 3.41).
- Motorcycles/mopeds had the highest FSI proportion of intersection injury crashes – 55% of motorcycle intersection crashes resulted in fatal or serious injury (Figure 3.42).
- Heavy freight vehicles were involved in 3% of intersection crashes and 5% of all other crashes.
- Intersection injury crashes involving motorcycles and heavy vehicles were more severe in terms of fatalities – 3% of crashes involving these vehicles resulted in a fatality (Figure 3.42).
- The proportion of intersection crashes involving heavy freight vehicles was higher on state-controlled roads than on locally controlled roads, while the proportion of motorcycle intersection crashes was lower on state-controlled roads.

Figure 3.40: Intersection injury crashes by primary vehicle type (2007–11)

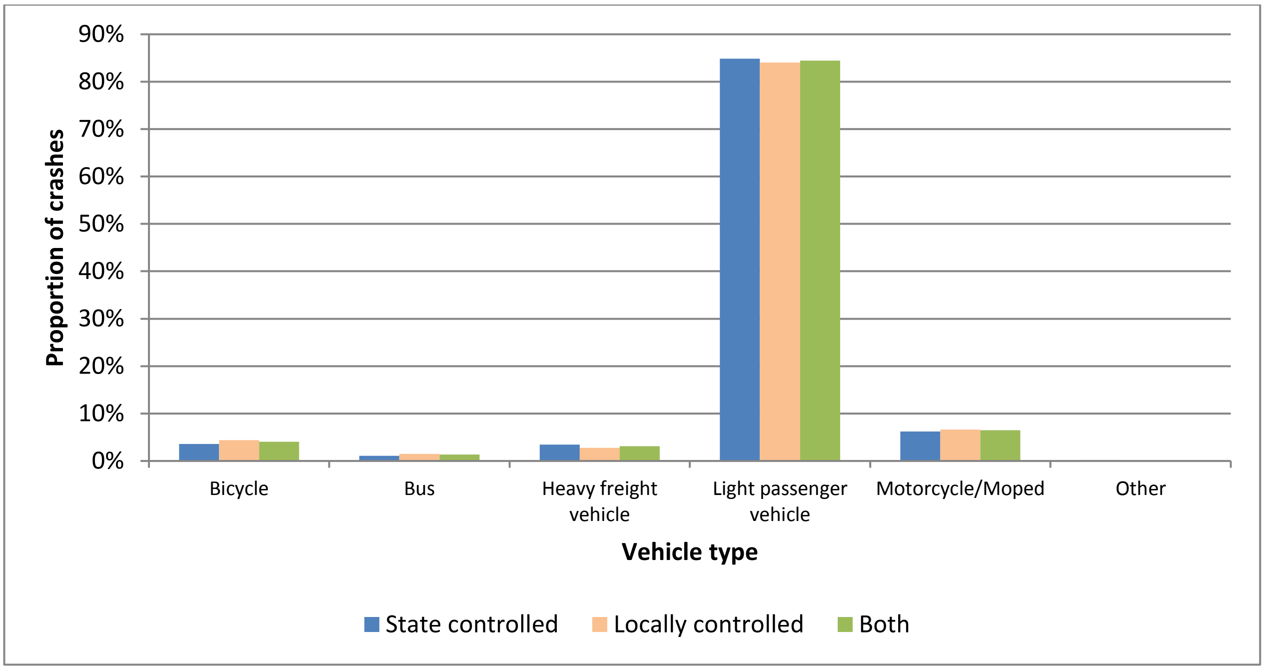


Figure 3.41: All other injury crashes by primary vehicle type (2007–11)

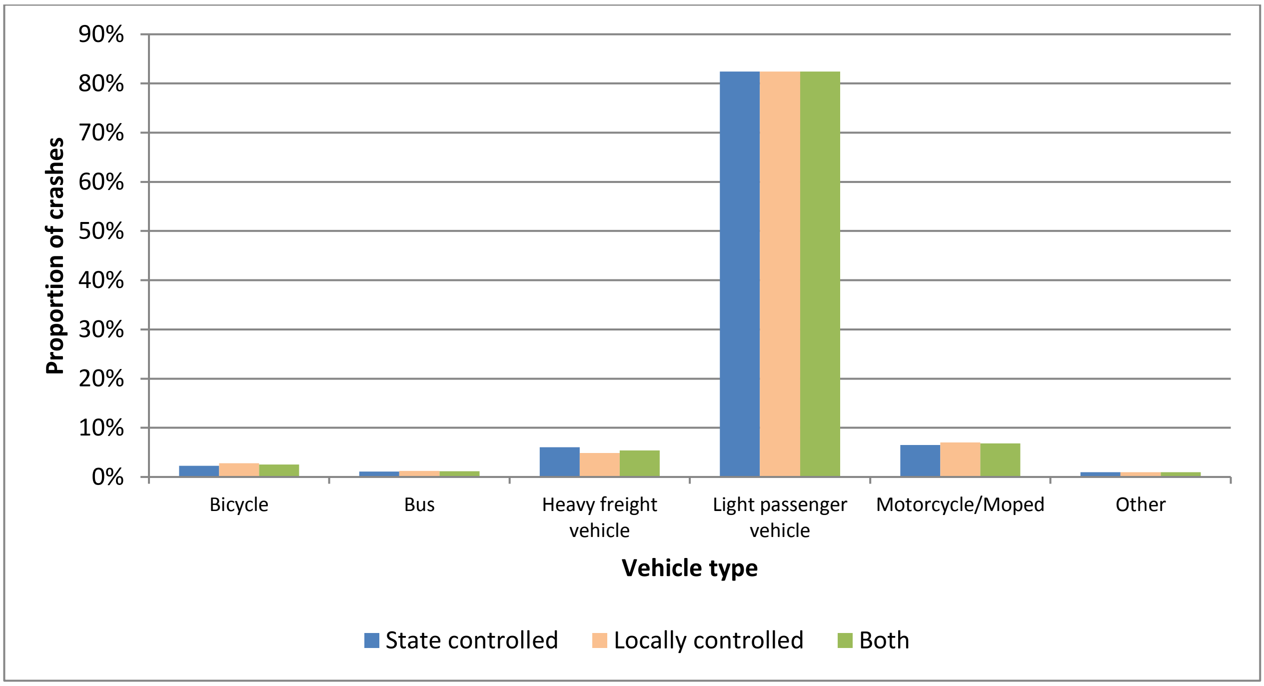
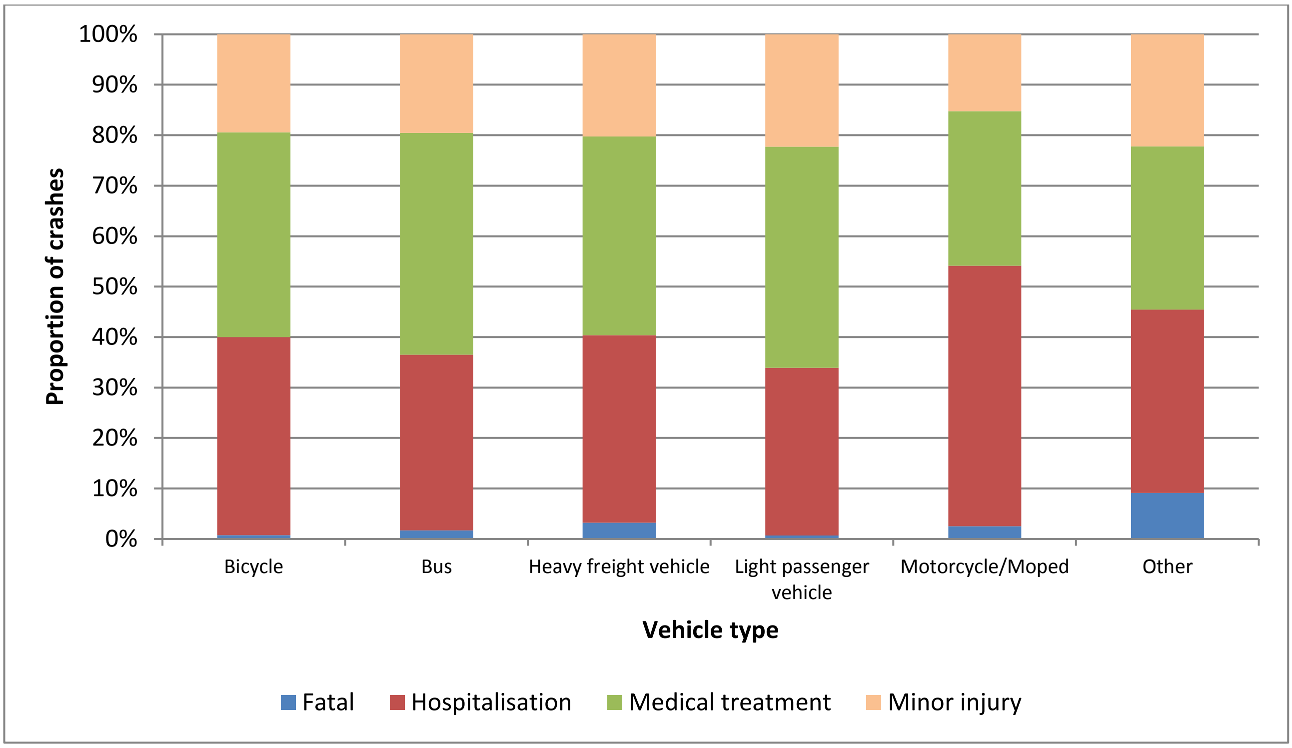


Figure 3.42: Intersection injury crashes by primary vehicle type and severity (2007-11)



3.21 Intersection Crash Rates and High Risk Sections – State-controlled Roads

Information on state-controlled roads with high risk intersections has been provided based on total crash numbers. The Department's derived 2013 willingness to pay (WTP) crash cost values have been used to estimate crash costs (Table 3.6).

Table 3.6: Willingness to pay crash cost ($ 2013)

Crash severity	Crash cost ($ 2013)
Fatal	8 147 446
Hospitalisation	365 761
Medical treatment	106 907
Minor injury	37 944

The top 20 high risk road sections in terms of intersection crashes are provided in this section. The complete list for all roads are provided as an attachment in an Excel Spreadsheet.

3.21.1 State Roads with a High Number of Intersection Crashes

Table 3.7 shows the top 20 road sections with the highest intersection injury crashes. The top 50 high risk intersection crash road sections are provided in Appendix B, Table B 1.

Table 3.7: Top 20 road sections with the highest number of intersection injury crashes (2007–11)

Road sections	Fatal	Hospitalisation	Medical treatment	Minor injury	Total
12A	2	102	192	79	375
20A	2	87	109	54	252
103	4	89	105	37	235
204	2	78	106	48	234
18A	6	94	88	45	233
10A	7	86	84	42	219
U14	2	55	100	58	215
11B	7	65	92	36	200
835	0	65	86	39	190
301	0	63	60	63	186
U20	1	56	75	45	177
U15	1	54	79	39	173
120	1	56	82	32	171
106	1	65	78	23	167
U18B	0	63	68	36	167
U12A	1	54	77	29	161
U19	0	50	65	45	160
10P	1	72	58	27	158
163	0	51	68	38	157
18B	4	61	62	29	156

3.21.2 State Roads with a High Intersection Crash Cost

Table 3.8 shows the top 20 road sections with the highest intersection injury crashes based on crash cost. The top 50 high risk intersection crash road sections based on crash cost are provided in Appendix B, Table B 2.

Table 3.8: Top 20 road sections with the highest intersection injury crash cost (2007–11)

Road sections	Fatal	Hospitalisation	Medical treatment	Minor injury	Total	Annual average crash cost ($)
10A	7	86	84	42	219	19 812 281
18A	6	94	88	45	233	18 876 301
11B	7	65	92	36	200	18 401 603
103	4	89	105	37	235	15 554 335
12A	2	102	192	79	375	15 425 247
10F	7	42	28	24	101	15 259 627
18B	4	61	62	29	156	12 525 963
20A	2	87	109	54	252	12 363 588
204	2	78	106	48	234	11 595 541
10C	6	18	7	2	33	11 258 522
U14	2	55	100	58	215	9 860 640
25A	2	57	42	29	130	8 546 748
10P	1	72	58	27	158	8 341 466
106	1	65	78	23	167	8 226 674

Road sections	Fatal	Hospitalisation	Medical treatment	Minor injury	Total	Annual average crash cost ($)
120	1	56	82	32	171	7 722 129
U20	1	56	75	45	177	7 671 113
U15	1	54	79	39	173	7 564 802
112	3	21	41	21	86	7 460 666
U12A	1	54	77	29	161	7 446 151
406	1	57	55	33	146	7 225 572

3.22 Summary Findings

A summary of the intersection crash findings includes the following:

- Intersection crashes accounted for 44% of all injury crashes, and 40% of FSI crashes on Queensland roads during the five year period.
- A lower proportion of intersection crashes (37%) resulted in fatalities or hospitalisation compared to all other crash types (40%).
- There was an overall reduction in intersection injury crashes of 15% over the 5 year (2007–11) period.
- Crashes at T-junctions made up 47% of the intersection injury crashes, followed by crashes at cross-intersections with 34%.
- DCA code 202 accounts for 25% of intersection FSI crashes on state-controlled roads and 19% on locally controlled roads.
- Most of the DCA 202 crashes that resulted in FSI (61%) occurred at signalised intersections.
- About 41% of intersection FSI crashes that occurred at signalised intersections were DCA code 202 crashes.
- Crashes at railway crossings had the highest FSI rate (52%) and highest fatality rate (9%), followed by multiple road intersections (42% FSI).
- Crashes at unlit intersections are more severe than other lighting conditions. Unlit intersections recorded the highest proportion of FSI and fatal night-time crashes.
- Most of the intersection injury crashes (60%) involved middle-aged controllers (25 to 59 years old).
- Intersection crashes at a location with a railway crossing sign as traffic control had the highest FSI rate (63%), followed by railway crossing controlled by lights/boom gates (53%).
- Intersections with no traffic control recorded the highest number of injury crashes (33%), followed by those with traffic lights (31%), give way signs (27%), and stop signs (8%).
- As the primary vehicle controller, male controllers were involved in 59% of all intersection injury crashes.
- Motorcycles/mopeds recorded the highest proportion of intersection FSI crashes (55%).
- The risk of a fatal intersection crash was highest for motorcycle/moped, heavy and special purpose vehicles.
- The top five contributing factors recorded for intersection injury crashes were disobeying road rules, young adult drivers (16 to 24 years old), senior adult drivers (60 and above), controller condition and alcohol.

4 ENGINEERING TREATMENTS AND FUNDING PROGRAMS

4.1 Suggested Treatments

This section provides a list of cost-effective treatments that may reduce the number and severity of intersection crashes considering the main issues identified in the crash analysis.

4.1.1 Traffic Signalisation Treatments

It was observed that the number of crashes at T-junctions with traffic signals and signage was half that of locations with no traffic control. Although some T-junctions may not warrant traffic signalisation (low daily traffic), there may be a number of intersections that would benefit from an upgrade to a signalised intersection or roundabout. This will separate oncoming traffic into phases to reduce the likelihood of right-angle crashes and right-through crashes.

At existing signalised intersections, increasing the right-turn phase intervals may reduce rear-end crashes (Chen & Meuleners 2013). As stated in the literature review, there can be significant reductions in serious injury crashes with this simple and cost-effective countermeasure. At intersections with a dedicated right-turn phase, drivers are relieved of having to determine a safe gap to make a turn movement across the oncoming lane. This reduces the chance of angle crashes.

Increasing the clearance phase (all-red) may also reduce the likelihood of right angle crashes, as drivers have more time to clear the intersection. This must be optimised so that drivers are not encouraged to run red lights. Phase changes that are too short may cause drivers to abruptly stop and increase rear-end crashes.

4.1.2 Dedicated Left-turn Lanes

Through-road speeds can be too high for vehicles to turn safely when turn lanes are not present. A dedicated left turn lane can increase the capacity of intersections and roadways by removing turning vehicles from the through-vehicle lane for improved intersection operations. Austroads (2012) found that an additional left turn lane reduced crashes by 20% in general. At intersections with high capacity, adding a dedicated left turn lane will increase mobility, as it removes stopped vehicles from through traffic. However, left turning vehicles in these lanes are known to block the sight lines of drivers at the intersection and may increase crash risk. The location of the stop and hold lines at the intersection should be located appropriately to ensure left turning lanes do not block the sight lines or restrict the safe intersection sight distance.

4.1.3 Right-turn Lane Treatments

Provision of dedicated right-turn lanes will reduce crashes related to right-turn manoeuvres which conflict with the opposing traffic stream when appropriate lengths, widths and tapers are used to provide sufficient storage capacity. Austroads (2012) found that there was a 30% crash reduction when a dedicated right-turn lane was added to signalised intersections. This treatment is more effective for rural areas (Lyon et al. 2007). Adding a right-turn lane with lengthened capacity can reduce the potential for rear-end collisions.

Banning right turn movement can reduce or eliminate the need for right-turn lanes. However, a right turn ban, may redirect the problem somewhere else.

4.1.4 Intersection Conflict Point Reduction

Staggered T-junctions and roundabouts can be used in place of cross-intersections to decrease the number of conflict points. According to the literature, a 94% decrease in serious injury crashes is possible with conversion to a staggered T-junction (Candappa et al. 2006).

4.1.5 Delineation, Signage of Intersections and Skid Resistance

Giving drivers sufficient warning of an upcoming intersection is critical for their safe negotiation of the intersection. This can be improved by ensuring line markings are in good condition, adequate signage is provided that warns of the oncoming intersection, and sufficient street lighting, adequate sight distance and traffic islands are provided.

Street lighting has been shown to decrease the average night-time crash rate by 30% (Arizona Department of Transportation 2009). Destination street lighting should also be provided that does not supplement vehicle headlights, but indicates the presence of an intersection.

Resurfacing of pavement through an intersection will improve skid resistance and remove any rutting present. This can improve the effectiveness of braking and in turn reduce rear-end crashes and angle crashes.

Stop signs at T-junctions have been attributed to a lower crash rate than those with no traffic control or give way signs. They are a cost-effective countermeasure that should be installed at T-junctions with no traffic control if appropriate.

4.1.6 Lane Narrowing and Vertical Deflection

Lane narrowing is commonly adopted on the minor approaches of rural intersections and has been shown to be effective in reducing vehicle approach speeds resulting in a reduction in right angle and rear end crashes (by 30–80%). Treatments include general channelisation installations, splitter islands, rumble strips on the outside shoulder, transverse rumble strips and mountable and non-mountable median installations.

Vertical deflections such as raised stop bars and raised platforms are provided at approaches to intersections to reduce vehicle speeds. The reduced speed improves safety by reducing the number and severity of crashes. Austroads (2011) reports that speed humps, a common form of vertical deflection, were effective in reducing the 85^{th} percentile speed in the order of 5–10 km/h and should lead to less severe crashes.

4.1.7 Red Light Cameras and Driver Compliance Measures

Installing red light cameras and signs that inform drivers of the use of them at signalised intersections has the potential to reduce right angle crashes. These can be particularly effective at locations where there has been a history of drivers disobeying traffic laws and running red lights. Red light cameras have been shown to reduce right angle crashes by 44% (De Pauw et al. 2014).

4.1.8 Median Openings

The crash analysis found that median openings without traffic control made up 58% of the intersection injury crashes at median openings, whilst those with give way signs (3%) and stop signs (3%) had far lower proportions. Where possible, limit median openings or install traffic control signage such as give way signs or stop sign, especially at frequently trafficked intersections.

4.1.9 Railway Crossings

Intersection crashes at railway crossings are less frequent but have the highest severity. Railway crossings controlled by lights only have higher risk so where possible, in addition to lights, bells, boom gates, barriers and signage should be installed. Boom gates/barriers have been found to reduce the incidence of railway crossing crashes by 70% over signage alone (Austroads 2012).

4.1.10 Roundabouts and Signalised Roundabouts

Roundabouts have been shown to have significantly results in reduce right angle and high speed crashes at intersections. Lower risk crashes, particularly rear end crashes, may still be prevalent, and an increase in crashes involving cyclists may occur. Signalised roundabouts have proven to be successful in catering for the safety of all road users with reductions in crashes related to poor judgement of gaps in circulating traffic, a reduction in cyclist related crashes, and a reduction in rear-end crashes between vehicles waiting to join the roundabout. The delay associated with signalised roundabouts remains constant compared to that of unsignalised roundabouts where delays can reach unacceptable levels, particularly in peak traffic. It is suggested that signalised roundabouts should only be adopted at existing roundabout locations rather than at other priority controlled or signalised intersections. The signalised roundabout should be in operation full time as part time signals result in driver confusion.

4.1.11 Roadside Hazard Treatment

Trees and utility poles present significant potential roadside hazards when located close to the carriageway. Barriers can also have low frangibility, which increases the severity of crashes. To reduce the severity of crashes with roadside furniture, remove trees and relocate utility poles away from intersections and edge lanes where possible. Install barriers where this is not possible to protect drivers, and replace non-frangible poles with frangible ones to reduce the force of impact.

4.1.12 Improved Pedestrian Intersection Treatments

There are a number of treatments available to improve safety for pedestrian movements through intersections. These include:

- visibility improvement treatments such as enhanced crossing signs, with flashing overhead lights, and in-roadway warning lights at unsignalised pedestrian crossings where there is an issue with vehicle stopping compliance
- excessive speed reduction measures termed perceptual countermeasures such as transverse or peripheral line marking, converging chevron pavement markings, pavement marking to reduce lane widths, and alternate guide post spacing and heights
- treatments at signalised intersections including installation of pedestrian signal phases, improvement to pedestrian signal timing and use of rest on red.

4.2 Funding Programs

Funding for road safety projects come under the Targeted Road Safety Programs (TRSPs) Investment Group. The program primarily provides funding for low-cost, high-benefit minor capital improvements on the road network to address actual or potential crashes that lead to high severity outcomes (fatalities and hospitalisations). High priority is given to treatments dealing with the three main crash types on Queensland roads namely; intersections, head-on and run-off-road crashes under TRSP business programs.

Available funding for dealing with intersection crashes under this program is listed in Table 4.1. A review of eligible treatments under the various programs indicates that the proposed treatments outlined in Section 4.1 above can be implemented under the current funding regime. Due to funding limitation, high risk intersections should be prioritised for improvement first.

Table 4.1: Funding programs for intersection crashes

TRSP Business Program	Description/selection criteria
Black Spot	Black Spot is a federally funded minor capital works program that aims to improve the safety of the national, state and local road networks through the implementation of high-benefit cost-effective, engineering countermeasures and safety treatments that target known and potential high severity (fatalities and serious injuries) crash sites at specific locations. Black Spot funding is prioritised to the highest safety benefit work identified through an annual development round process. The Black Spot Programme can be applied to both discrete sites and to treating road lengths (three kilometres or greater. The maximum funding allocation for successful Black Spot projects is $2m.
Safer Roads Sooner	Safer Roads Sooner (SRS) is a state funded minor capital works program that aims to improve the safety of the state-controlled road network through the implementation of high-benefit cost-effective, engineering countermeasures and safety treatments that target known and potential high severity (fatalities and serious injuries) crash sites at specific locations such as, intersections, curves and short road sections. SRS funding is prioritised to the highest safety benefit work identified through an annual development round process. The maximum funding allocation for successful SRS projects is: ▪ $3.5m (for reactive projects – locations with significant crash history) ▪ $0.5m (for proactive projects – locations with potential for significant crashes due to the road environment)
Innovation trials and capability	Innovations Trials and Capability provides limited state funding to activities to trials and other innovative work and processes to support and improve the overall Targeted Road Safety Program.
Safety mass actions	Mass Actions is a state funded program to implement particular treatments (or a suite of treatments) to target a particular safety issue across the state-controlled network.
Route actions	Route Actions is a state funded program to address key safety concerns on the state-controlled network identified for the whole of a road segment or route, instead of at individual discrete locations as is the focus of the SRS and Black Spot programs.
Targeted safety interventions	Targeted Safety Interventions is a state funded program to treat particular safety issues identified on the state-controlled network that would not otherwise be addressed through the other subprograms of Targeted Road Safety Program. Sites will have funding prioritised on a case-by-case basis.
Road safety minor works	Road Safety Minor Works provides a limited state funded allocation to each of the Department's 12 districts to address identified localised safety needs at a local level on the state-controlled network. Although districts are required to establish and deliver a full program of works at the start of each financial year, funding is provided with the flexibly for the district to reprioritise funding to respond to low-cost emerging safety issues as they occur throughout the year.
Vulnerable users	This is a state funded program to treat state-controlled network locations with safety issues specifically related to cyclists, pedestrians and motorcyclists.
Emerging crash location remediation	Emerging crash location remediation provides state funding to sites on the state-controlled network, identified through emerging crash site history reports, that are showing a recent increase in the crash rate over a short period of time, which may result in more serious injuries and fatalities if left untreated. Funding is provided as required to sites identified throughout the year with no set annual nomination round.
Fatal crash remediation	Fatal crash remediation provides limited state funding to sites on the state-controlled network where a fatal crash has occurred and a crash investigation report has recommended immediate low-cost remedial treatments. Funding is provided as required to sites identified throughout the year with no set annual nomination round. It covers minor capital improvements that are low-cost, high-benefit (value-for-money) engineering treatment solutions to address fatal crash sites as recommended in final crash investigation reports as immediate interim remedial measures that fit within the $250,000 funding limit.

Source: Queensland Department of Transport and Main Roads Investment_sub_program_template_DM_20160613.xls

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The key findings from the analysis of intersection crashes on Queensland roads include the following:

- Intersection crashes account for 44% of all injury crashes and 40% of FSI crashes on Queensland roads during the five year period.
- On state-controlled roads, intersection crashes accounted for 40% of all injury crashes and 36% of FSI crashes, even though it accounts for less than 5% of the network.
- There was an overall reduction in intersection injury crashes of 15% over the five years (2007–11).
- The top five contributing factors recorded for intersection injury crashes were disobeying road rules, young adult drivers (16 to 24 years old), senior adult drivers (60 and above), controller condition and alcohol.
- Most of the intersection injury crashes occurred at T-junctions (47%), cross-intersections (34%) and roundabouts (10%), the three most common intersection types.
- The majority of the intersection injury crashes occurred at intersections with no traffic control (33%), intersections with traffic lights (31%) and give way signs (27%).
- The major intersection injury crashes have been angle crashes (57%), rear-end (21%), hit object (10%) and pedestrian crashes (4%), hence intersection programs should focus on treatments that address these crash types.
- DCA code 202 crashes account for 25% of intersection FSI crashes on state roads and 19% on locally controlled roads.
- About 61% of DCA code 202 crashes that resulted in FSI occurred at intersections with traffic lights.
- About 41% of FSI and 37% of all injury crashes that occurred at intersections controlled by traffic signals were DCA code 202 crashes.
- About 86% of the intersection angle injury crashes occurred at T-junctions (43%) and cross-intersections (43%).
- The majority of rear-end intersection injury crashes occurred at intersections with no traffic control (39%), intersections with traffic lights (33%) and give way signs (27%).
- Most of the rear-end intersection injury crashes occurred at T-junctions (55%), cross-intersections (24%) and roundabouts (10%).
- Most of the pedestrian injury crashes at intersections occurred at T-junctions (49%) and cross-intersections (44%), especially those controlled by traffic lights. More than half (52%) of pedestrian injury crashes at intersections occurred at intersections controlled by traffic lights.
- The majority of hit object intersection injury crashes occurred at T-junctions (52%), followed by roundabouts (19%) and cross-intersection (16%).
- Most of the intersection injury crashes involving parked vehicles occurred at T-junctions (73%).
- Railway crossings had the highest FSI rate (52%) and highest fatality rate (9%), followed by multiple road intersections (42% FSI).

- Railway crossings controlled by sign only had the highest FSI rate (63%), followed by railway crossings controlled by flashing lights (53%).
- There are more intersection injury crashes (89%) on low-speed roads (below 80 km/h) than all other injury crashes (73%).
- Middle-aged controllers (25 to 59 years old) make up the largest proportion of primary vehicle controllers involved in intersection injury crashes (60%), partly because they have the widest range.
- Disobeying road rules was a factor in a high proportion of intersection injury crashes (79%), more than for all other injury crashes (67%).
- Crashes at unlit intersections are more severe than other lighting conditions – unlit intersections recorded the highest proportion of FSI and fatal night-time crashes.
- Give way signs (27%), no traffic control (33%), traffic lights (31%), and stop signs (8%) were attributed to the most intersection injury crashes.
- As the primary vehicle controller, male drivers were involved in 59% of the intersection injury crashes.
- The risk of an FSI intersection crash was highest for motorcycle/moped (55%), heavy vehicles (40%) and cyclists (40%).

Based on the literature review and the crash analysis the following engineering treatments are recommended for implementation at intersections.

- Install traffic lights at T-junctions and cross-intersections to separate oncoming traffic by phases to reduce the likelihood of right-angle crashes and rear-end crashes.
- At existing traffic lights, increase the right-turn phase intervals to decrease the frequency of rear-end crashes, increase the clearance (all-red) phase and add a dedicated right-turn phase interval or if there is currently a filter right-turn or part time right-turn/arrow provision.
- Where possible, channelise left-turn/right-turn lanes at intersections to reduce rear-end crashes, and replace cross-intersections with roundabouts (less conflict points and low angles of impact) or staggered T-junctions.
- Signalise existing roundabouts to regulate speed of circulating traffic, and reduce the likelihood of unacceptable delays on certain legs.
- Provide pedestrian and cyclist facilities at roundabouts to counter the increased risk to pedestrians and cyclists.
- Increase delineation at intersections (linemarkings, signage, street lighting and traffic islands), especially stop signs at T-junctions.
- Ensure adequate sight distances to intersections by removing roadside obstructions.
- Install red light cameras and signs informing the public of these treatments at signalised intersections to decrease right angle crashes.
- Limit median openings where possible, and place give way signs or stop signs at frequently trafficked median openings.
- Resurface pavements to improve skid resistance.
- In addition to flashing lights, install barriers, bells, boom gates and signage at railway crossings to notify drivers.
- Remove hazardous roadside furniture away from intersections and edge lanes, or install barriers to protect drivers.

5.2 Follow-up Study

It is recommended to further investigate the safety implications of site specific characteristics. The study should inspect and investigate the site characteristics of intersections with higher than average and lower than average crash rates. The results from the investigation will help identify design and operational characteristics that influence road safety and to develop relationships between road features and crashes.

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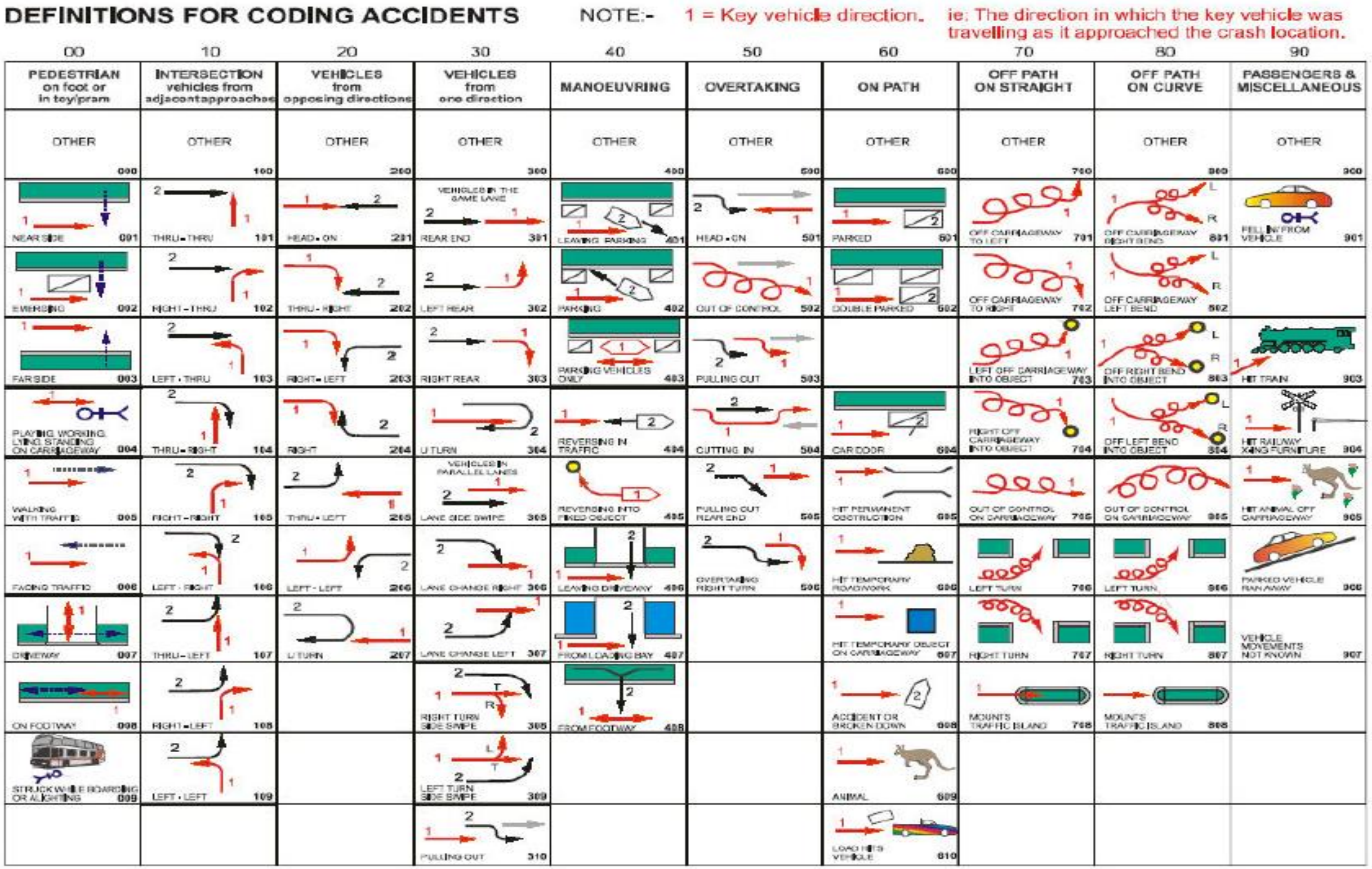
APPENDIX A DEFINITIONS FOR CRASH CODING



APPENDIX B STATE-CONTROLLED ROADS HIGH INTERSECTION CRASH SECTIONS

Table B 1: Top 50 state-controlled roads with the highest number of intersection injury crashes (2007–11)

Road sections	Fatal	Hospitalisation	Medical treatment	Minor injury	Total
12A	2	102	192	79	375
20A	2	87	109	54	252
103	4	89	105	37	235
204	2	78	106	48	234
18A	6	94	88	45	233
10A	7	86	84	42	219
U14	2	55	100	58	215
11B	7	65	92	36	200
835	0	65	86	39	190
301	0	63	60	63	186
U20	1	56	75	45	177
U15	1	54	79	39	173
120	1	56	82	32	171
106	1	65	78	23	167
U18B	0	63	68	36	167
U12A	1	54	77	29	161
U19	0	50	65	45	160
10P	1	72	58	27	158
163	0	51	68	38	157
18B	4	61	62	29	156
406	1	57	55	33	146
105	1	43	64	37	145
809	1	51	50	35	137
647	1	46	66	20	133
25A	2	57	42	29	130
10M	1	48	55	24	128
11A	0	47	58	23	128
116	0	34	64	26	124
153	2	34	45	33	114
833	0	50	47	17	114
U88	2	29	52	29	112
N239	1	34	50	23	108
U91	0	41	51	15	107
22B	0	32	44	28	104
U16	0	25	52	27	104
196	1	38	36	26	101
10F	7	42	28	24	101
832	2	37	40	18	97
U95	1	33	34	29	97
109	1	36	40	19	96
121	2	37	36	21	96
840	0	42	34	20	96

Road sections	Fatal	Hospitalisation	Medical treatment	Minor injury	Total
612	1	34	48	12	95
200	0	20	45	29	94
114	0	21	54	15	90
112	3	21	41	21	86
U96	1	32	40	13	86
401	0	22	44	17	83
133	0	31	34	17	82
10G	2	27	36	16	81

Table B 2: Top 50 state-controlled roads with the highest intersection injury crash costs (2007–11)

Road sections	Fatal	Hospitalisation	Medical treatment	Minor injury	Total	Annual average crash cost
10A	7	86	84	42	219	19 812 281
18A	6	94	88	45	233	18 876 301
11B	7	65	92	36	200	18 401 603
103	4	89	105	37	235	15 554 335
12A	2	102	192	79	375	15 425 247
10F	7	42	28	24	101	15 259 627
18B	4	61	62	29	156	12 525 963
20A	2	87	109	54	252	12 363 588
204	2	78	106	48	234	11 595 541
10C	6	18	7	2	33	11 258 522
U14	2	55	100	58	215	9 860 640
25A	2	57	42	29	130	8 546 748
10P	1	72	58	27	158	8 341 466
106	1	65	78	23	167	8 226 674
120	1	56	82	32	171	7 722 129
U20	1	56	75	45	177	7 671 113
U15	1	54	79	39	173	7 564 802
112	3	21	41	21	86	7 460 666
U12A	1	54	77	29	161	7 446 151
406	1	57	55	33	146	7 225 572
10E	3	23	25	12	63	7 196 569
153	2	34	45	33	114	6 958 747
832	2	37	40	18	97	6 957 464
121	2	37	36	21	96	6 894 705
835	0	65	86	39	190	6 889 657
10N	3	21	14	12	50	6 815 069
U88	2	29	52	29	112	6 712 300
809	1	51	50	35	137	6 694 929
17B	2	37	25	11	75	6 583 622
647	1	46	66	20	133	6 557 439

Road sections	Fatal	Hospitalisation	Medical treatment	Minor injury	Total	Annual average crash cost
10M	1	48	55	24	128	6 498 903
105	1	43	64	37	145	6 424 229
301	0	63	60	63	186	6 369 567
U18B	0	63	68	36	167	6 335 721
10G	2	27	36	16	81	6 125 239
U90	2	24	31	9	66	5 745 754
1102	2	23	26	8	59	5 558 106
163	0	51	68	38	157	5 473 072
U19	0	50	65	45	160	5 388 897
196	1	38	36	26	101	5 376 312
N239	1	34	50	23	108	5 360 276
174	2	18	29	15	64	5 309 611
489	2	18	26	21	67	5 290 999
109	1	36	40	19	96	5 262 412
612	1	34	48	12	95	5 234 037
202	2	16	24	11	53	5 026 044
111	2	18	18	7	45	5 013 705
U95	1	33	34	29	97	4 990 555
U96	1	32	40	13	86	4 924 270
40A	2	18	11	6	37	4 856 446