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FINAL REPORT

Project Title: R28 Review and Analysis of Head-on, Run-off-road and Out-of-control Crashes on Queensland Roads

Year 1 – 2014/15

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arrb GROUP

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R28 Review and Analysis of Head-on, Run-off-road and Out-of-control Crashes on Queensland Roads

SUMMARY

A review of crash data identified head-on crashes, run-off-road crashes and intersection crashes as the three most severe crash types on Queensland roads. In order to focus its safety activities in the right areas Queensland Transport and Main Roads (TMR) commissioned ARRB Group to determine the contributing factors and key drivers behind these crash types. This will enable more specific and focused strategies to be adapted for improved safety outcomes for these high risk crash types.

The study involved literature review and detailed analysis of head-on, run-off-road and out-of-control crashes on Queensland roads.

- Forty per cent of all injury crashes on QLD roads resulted in fatal or serious injury (FSI)
- Head-on crashes account for 4% of all injury crashes, 6% of FSI on QLD roads, and 7% of FSI on state-controlled roads
- Head-on crashes are more severe than other crash types - about 61% of all head-on crashes resulted in fatal or serious injury compared to 40% for all injury crash types
- The proportion of FSI head-on crashes is higher on state-controlled roads (64%) than those on locally controlled roads (56%)
- Only 3% of all head-on injury crashes on QLD roads were due to overtaking vehicles; hence the provision of overtaking lanes should be provided as a traffic operation and capacity measure or at specific sites with severe sight distance restriction or known to have recorded high head-on crashes due to overtaking
- Run-off road crashes including out-of-control crashes represent 26% of all injury crashes, 33% of FSI on QLD roads and 36% of FSI on state-controlled roads
- The risk of head-on and run-off-road injury crashes on curves was higher than for all injury crashes (56% of head-on injury crashes; 44% of run-off-road injury crashes and 47% of out-of-control injury crashes occurred on curves compared to 23% for all crash types)
- Young drivers/riders (17-24 years old) make up the largest proportion of the primary vehicle controllers involved in head-on, run-off-road and out-of-control crashes injury crashes
- As primary vehicle controller, male drivers are over-represented (about 70%) in head-on, run-off-road and out-of-control crashes injury crashes
- The risk of a fatal head-on crash involving a heavy vehicle was higher compared to other vehicles
- Motorcycles/mopeds were over-represented in head-on, run-off-road and out-of-control injury crashes
- The top five contributing factors as recorded for these crash types were disobeying the road rules, young adults (17-24 years age group), road condition and controller condition and alcohol related.

The engineering treatments which may be implemented to reduce the incidence and/or severity of head-on and run-off-road crashes as a mass action treatment include:

- Road centreline treatment (central hatching, wide centreline with or without audio-tactile line marking) to reduce the incidence of head-on and cross median crashes
- Median barriers and 2+1 lane treatment to prevent head-on crashes and reduce the incidence and severity of cross median crashes
- Improve signage, delineation and speed reduction measures especially on curves to reduce the incidence of head-on and run-off-road crashes (e.g. provision of chevron alignment markers, guideposts, edge lines, raised reflective pavement markers, vehicle activated signs (VAS), advisory speed signs).
- Improve skid resistance and road surface condition
- Roadside hazard treatment such as hazard protection with safety barriers, hazard removal (point objects such as trees, poles/posts, etc.), improved design and application of barriers and impact attenuators, batter slopes management and replacement of non-frangible poles with frangible ones
- Shoulder treatment – sealing, widening and edge treatment to make it easy for errant drivers to re-enter the travel lanes, and avoid steep angle entry which do lead to head-on and run-off-road opposite site due to over-steering.

The following further research opportunities identified from the study are recommended:

- Comprehensive analysis including on-site review of crashes involving motorcycles, heavy vehicle crashes and fatigue related crashes
- Using curvature data from the ANRAM rating of the state-controlled roads, investigate the relationships between curve radii and crashes, especially with head-on and run-off-road crashes
- Develop a uniform and consistent method for prioritising high crash sites for treatment.

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1 INTRODUCTION

1.1 Background

A review of existing historical crash data has identified three key crash types to occur on Queensland roads, namely intersection crashes, run-off-road crashes and head-on crashes.These crash types account for about 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 Queensland Transport and Main Roads (TMR) to focus its activities in the right areas, the key drivers behind these crash types need to be understood, and the numerous variables attribute to these crashes identified. This understanding will enable more specific and focused strategies to be adapted for improved safety outcomes.

This project is being conducted over a two year period. The first year tasks involved a literature review and analysis of run-off-road, head-on injury crashes and out-of-control crashes on Queensland roads. The second year consists of a review of intersection crashes.

This report presents the findings of year 1 activities – review and analysis of head-on, run-off-road and out-of-control injury crashes.

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 evaluate existing strategies currently undertaken to address run-off-road and head-on crashes and determine their usefulness in reducing serious crashes
- Undertake comprehensive analysis of run-off-road and head-on crashes on the Queensland road network, on both local and state roads
- Identify potential new engineering treatments that may provide appropriate strategies to reduce run-off-road and head-on crashes

2 LITERATURE REVIEW

A literature review and internet search was undertaken to identify and evaluate existing strategies currently undertaken to address run-off-road and head-on 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 Australian Transport Index (ARTI), TRANSPORT, and Transportation Research Information Services (TRIS) databases, whose content is coordinated by ARRB Group, the OECD and the U.S. Transportation Research Board respectively.

2.1 Background Research

There has been significant national and international research in recent years in head-on and run-off-road crashes. These include Austroads research undertaken to feed into future updates of the Austroads Guide to Road Safety.

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 relevant Austroads reports include:

- Investigation of Key Crash Types – Run-off-road and Head-on Crashes in Urban Areas: Final Report
- Road Safety Engineering Risk Assessment: Part 8: Rural Head-On Crashes
- Road Safety Engineering Risk Assessment: Part 10: Rural Run-Off-Road Crashes
- Improving Roadside Safety Summary Report
- Effectiveness of Road Safety Engineering Treatments
- Guide to Road Safety Part 8: Treatment of Crash Locations.

2.2 Head-on Crashes

2.2.1 Definition

Austroads (2014a) defines head-on crashes as 'an event in which a vehicle departs from its laneway into opposing traffic, such that any portion of the leading edge of its vehicle strikes any portion of the leading edge of an opposing vehicle'.

2.2.2 Head-on Crash Contributory Factors

The factors contributing to the occurrence and severity of head-on crashes can be classified under road environment factors, human factors and vehicle factors (Austroads 2014a, Bahar 2008).

Road environment factors

The road environment factors include (Austroads 2010a, Austroads 2014a, Bahar 2008, Larsen & Kines 2002, and Newman et al. 2008):

- road type – most head-on crashes occurred on 2-lane, 2-way undivided roads
- poor horizontal and vertical curvature especially complex curves where there is more than one curve within 100 m of each other and steep downhill gradients leading into curves.
- narrow pavement width
- pavement edge break (vertical edge > 6.35 cm increases crash severity; result in steep angle entry which may lead to over-steering onto the opposing lane)

- poor delineation – particularly on curves
- poor sight distance for overtaking
- insufficient overtaking opportunities - proportion of head-on crashes due to overtaking is comparatively small
- imposing hazard very close to road - it is assumed that drivers may be travelling closer to the centre of the road to provide a conscious buffer from the roadside infrastructure.

The key human related contributing factors to head-on crashes include (Austroads 2010a, Bahar 2008):

- straying onto the opposite lane (due to inattention and/or inexperience)
- driver fatigue and impairment
- speeding – travelling too fast for the road environment and speed limit
- driver inattention due to internal or external distraction
- over-correcting after straying onto the road shoulder
- evasive manoeuvres to avoid an obstacle
- driver age and inexperience

Austroads (2014a) reported that vehicle age is a factor in head-on crashes with older vehicles associated with higher incidence of head-on crashes (Austroads 2014a).

2.2.3 Head-on Crash Treatments and their Effectiveness

Due to the high energy impacts head-on crashes result in severe crash outcomes. Engineering treatments aimed at reducing the incidence and severity of head-on crashes and their effectiveness are presented in the following sections. Crash reduction values, where possible, derived from Austroads (2012) and international research have been reported.

Horizontal alignment

Austroads (2008) indicated that curve widening and improvement may be necessary to prevent vehicles from travelling outside their lane and closer to the centre of the road. There are several ways in which the horizontal alignment of a roadway may be modified to improve safety. These include increasing the radius, providing transition curves between the straight and the bend, eliminating compound curves and improving superelevation (Austroads, 2014d).

Austroads research indicates about 10 to 50 per cent reduction in head-on crashes for increasing the radius of horizontal curves (Austroads 2014a).

Superelevation of a road is intended to counteract the centrifugal forces acting on a vehicle by slightly sloping the road on curves. It contributes to improved drainage and road surface friction (Austroads (2012). Research indicates up to 50% reduction in head-on crashes due to reconstruction of superelevation on a curve (Austroads 2009).

Vertical alignment

Vertical realignments include reduction of the grade, increasing the radius of the crest for adequate sight distance and minimising the vertical acceleration changes (Austroads, 2014d). iRAP (2014) indicates a 10-25% crash reduction for vertical curve realignment.

Curve advanced warning

Horizontal alignment signs can be used to provide drivers with advanced warning of a curve, or multiple curves ahead. Austroads research (2009) indicates a 30% reduction in head-on crashes (Austroads 2009) and 25% in all casualty crashes (Austroads 2012) for the installation of curve warning signs.

Advisory speed warning signs and speed reduction measures

Speed is a major factor in the occurrence and severity of rural crashes and head-on crashes. Small changes in speeds can result in significant crash and injury reductions or increases (Austroads 2010). A study by Taylor et al. (2002) reported that a 10% increase in mean speed on rural single carriageway roads can result in a 30% increase in fatal and serious crashes. Advisory speed warning signs are typically used to aid in reducing speeds on through roads and in advance of bends. Austroads (2009a) indicated a 30% reduction in crashes can be expected in head-on crashes with the introduction of advisory speed signs on curves.

Lane width

As reported in Section 2.2.2 narrow pavement/lane widths are considered to be a contributing factor in head-on crashes. Austroads (2014a) reported that for lane widths less than 3.5 m, there may be benefit in lane widening. However, beyond this point there may be no safety benefit. Austroads (2014d) provide the following crash reduction potentials for carrying out lane widening:

- from 2.7 m to 3.0 m: 13%
- from 3.0 m to 3.3 m: 19%
- from 3.3 m to 3.6 m: 5%

Research indicates wide centreline treatment (WCTL) provides over 30% reduction in injury crashes so installing WCLT which by reducing the lane width to 3.25 m from 3.5 m will have net safety benefit. The increase in crash risk due to the reduced lane width is far less compared to the reduction in crashes due to the WCTL treatment.

Shoulder treatment

The provision of a wider, sealed shoulder may provide a greater area for errant vehicles to recover and hence contribute in reducing head-on crashes. Shoulder edge treatment make it easy for errant vehicles to re-enter the travel lanes, i.e. prevent steep angle entry which may lead to head-on crashes due to over-steering. Shoulder sealing is reported to have the following crash reduction potential:

- 40% reduction in head-on crashes (Austroads 2009)
- 30% reduction in all casualty crashes (Austroads 2012)
- 25-40% reduction in all crashes iRAP (2014).

Sight distance

Austroads (2012) provides a crash reduction factor of 30% for all casualty crashes for the improvement of sight distance in a rural environment.

Overtaking lanes

The presence of slow vehicles on a two-lane two-way road, together with limited opportunities for overtaking, is likely to increase congestion and driver frustration which may result in crashes occurring due to risky overtaking manoeuvres. Installation of an additional lane provides a much safer overtaking opportunity as well as improving the general flow of traffic along the roadway by breaking up the vehicle platoons (Austroads, 2014d).

Research indicates that overtaking lanes have the following benefits:

- 30% reduction in head-on crashes (Austroads (2009)
- 25%-40% reduction in casualty crashes (Austroads 2012; iRAP 2014).

Physical medians and road duplication

Dual carriageways and physical median provides a safety benefit in separating opposing traffic reducing the chances of head-on crashes in both urban and rural environments. iRAP (2014) indicates a crash reduction value of 25-40% for casualty crashes for road duplication. Austroads (2009) provides a head-on crash reduction factor of 90% for the installation of a median on an existing carriageway.

Austroads (2012) provides crash reduction of casualty crashes for the installation of a constructed median (urban) of 45% and a constructed median (rural) of 55%.

Centreline treatments and painted medians

Overall, centreline treatments (centreline, wide centreline, profiled centrelines and hatching) provide guidance to road users of the road ahead. Austroads (2012) indicates a crash reduction factor of 20% for all casualty crashes for the installation of centrelines and a 30% reduction for edge lines and centreline combined.

Whittaker (2013) examined the safety benefit of wide centreline treatments on the Bruce Highway in Queensland. The results indicated a 75% reduction in head-on crashes and a 59% reduction in fatal and serious injury (FSI) crashes. These results are based on limited data of a two years before and one year after treatment crash data.

iRAP (2014) indicated a crash reduction of 10-25% for the installation of a painted median, whilst. Austroads (2012) indicates a 15% reduction in casualty crashes. Levett et al (2009) indicated that painted medians needed to be at least 1.0 metre in width to maximise the beneficial effect on reducing crossover crashes. It was also indicated that further enhancement could be achieved by incorporating audio-tactile profile in the line marking, and further still with a wire rope barrier in the median.

For the installation of profiled centrelines Austroads (2012) indicates a crash reduction factor of 20% for all casualty crashes and a 30% reduction in head-on crashes.

Road surface

It is important that the road surface has an appropriate level of skid resistance in both wet and dry conditions. This is particularly important on curves and high-crash intersections (Austroads 2014a). Austroads (2012) provides a crash reduction factor of 35% for all crash types for improving the skid resistance of the road surface

Median safety barriers

Safety barriers include a range of devices to restrict lateral movement of errant vehicles. The device is designed to guide vehicles back on to the roadway or to bring vehicles to a stop. These may include flexible barriers such as wire rope, semi rigid barriers such as W-Beam, and rigid barriers such as concrete barriers. Where large physical medians (at least 10 m) cannot be used it is suggested that a median barrier be used to prevent errant vehicle crossing into the opposing traffic.

Marsh and Pilgrim (2010) reported on the performance of a wire rope barrier on a 3.5 km narrow median (1.5 m) installation on Centennial Hwy, New Zealand. The Centennial Hwy installation was the first use of a median barrier on a two-lane, two way road in New Zealand. Crash data analysis indicated there was 12 fatal crashes and 4 serious injury crashes during the nine years prior to the installation of wire rope barrier. Since then (2005 to 2009), no fatal or serious injury crashes were recorded at the site. It was concluded that the use of the wire rope barrier was proven to significantly reduce crash severity and is considered an appropriate solution when retrofitting existing roads, particularly in constrained environments.

iRAP (2014) indicates a crash reduction factor of 60% or more for the use of a median barrier whilst Austroads (2014d) reported the following crash reductions:

- 32% – change rigid barrier to less rigid type
- 70-86% – flexible barrier

Bergh, Carlsson & Larsson (2003) reported at least a 50% reduction in serious injury crashes for a 2+1 lane with wire rope barrier in Sweden when compared to a single carriageway road.

2.2.4 Vehicle Technology and Design

Safety features in new and future vehicles will play an important role in reducing the incidence and severity of head-on crashes. In vehicle technology provides measures to assist drivers to remain alert on the roadway, help maintain control of their vehicle, and assist in the event of a collision. This may include vehicle technology such as:

- Electronic stability control – assists the driver to maintain control of the vehicle when the steering and direction of travel do not correspond.
- Anti-locking braking systems – prevents wheel lock up when braking.
- Vehicle safety and testing – vehicle testing aimed at improving safety performance of vehicles.
- Lane departure warning – sensors detect the position of the vehicle relative to a lane or edge line. The driver is alerted when the vehicle approaches the line without indicating.
- Collision warning – sensors or cameras detect whether a collision may be imminent.
- Brake assist – senses whether emergency braking is being applied and ensures maximum braking is applied. This significantly reduces stopping distance.
- Adaptive headlights – sensors determine the direction the vehicle is headed and adjusts the headlights accordingly to provide a better view of the road around curves during night time driving.
- Fatigue monitoring – intelligent transport systems that incorporate fatigue monitoring e.g. tracking of eye movement.
- Driver workload management – system to restrict the delivery of information from mobile phones or other devices that may distract the driver from the primary driving task.

2.3 Run-off-road Crashes

2.3.1 Definition

Austroads (2014e) defines run-off-road crashes as occurring ‘when a vehicle leaves the road and often collides with a roadside object such as a tree or pole’. An Austroads study found that 79% of urban run-off-road casualty crashes in Australia resulted in a collision with a roadside object (Austroads, 2014a).

2.3.2 Run-of-road Crash Contributory Factors

The factors contributing to the likelihood and severity of run-off-road crashes can also be classified into road environment factors, human factors and vehicle factors.

The road environment factors include (Austroads 2010a, Austroads 2014a, Bahar 2008, Larsen & Kines 2002, and Newman et al. 2008):

- roadside hazard and inadequate clear zone
- horizontal and vertical curvature especially complex curves where there is more than one curve within 100 m of each other and steep downhill gradients leading into curves
- unsealed or narrow shoulder width
- pavement edge break (vertical edge > 6.35 cm increases crash severity; result in steep angle entry which may lead to opposing side run-off road crash)
- poor delineation – particularly on curves

The key human related contributing factors to head-on crashes include (Austroads 2010b, Austroads 2014a, Bahar 2008):

- lost directional control due to road surface condition
- driver fatigue and impairment
- excessive speed – travelling too fast for the road environment and speed limit particularly on bends
- driver inattention due to internal or external distraction
- evasive manoeuvres to avoid an obstacle
- driver age and inexperience

Vehicle related contributing factors include vehicle failure and vehicle technology:

- vehicle failure due to tyre blow-out or steering system failure (Pomerleau 1996 cited in Bahar 2008)
- vehicle age with older vehicles associated with high incidence in run-off-road and head-on crashes. Austroads 2014a reports that new technologies such as anti-locking braking, electronic stability control, and improved crash performance can help reduce the incidence and severity of these crashes.

2.3.3 Run-off-road Countermeasures and Effectiveness

Engineering treatments have been used over the years to address the occurrence and severity of run-off-road crashes. These treatments are aimed at:

- keeping vehicles on the road by reducing the risk of driver error
- minimising chance of errant vehicle rolling over or crashing by providing better chance of recovery
- reducing crash severity.

The following sections summarise the types of treatments used and their effectiveness based on their crash reduction potentials.

Clear zone and roadside hazard removal

A clear zone is an area adjacent to the edge of the trave lane where errant vehicles may travel without striking any hazards. The provision of shoulders and clear verges can play a key role in decelerating vehicles, but only in departures occurring at very low angles to the road (Austroads, 2014b). Austroads (2014b) concluded from a number of studies undertaken that rural run-off-road casualty crashes generally occur into the roadside rather than along it.

Ideally the clear zone should be free of hazards, but if this cannot be achieved the hazards within the clear zone should be protected (barrier shielded) or designed to be frangible.

Austroads (2011) investigated the relationship between clear zone and crash outcomes. It found that the relative risk of run-off-road casualty crashes to the left reduced with increasing clear zone width.

Peng et al (2012) found that run-off-road crash frequency and severity both decreased with wider lateral clearance by reducing the likelihood of a run-off-road vehicle hitting an object.

Peng et al (2012) discovered that the benefits of improving roadside conditions such as shoulder width, lateral clearance and side slope condition was greater on horizontal curves than on straight sections.

iRAP (2014) indicates a crash reduction factor of 40-60% for all casualty crashes for the use of safety barriers. Austroads (2014d) provides the following casualty crash reduction factors:

Roadside protection – safety barriers

Safety barriers can be used to prevent errant vehicle leaving the road striking roadside hazards. Barriers should be used where the potential damage caused by the hazard is greater than that of the barrier itself.

Austroads (2014a) suggests that barrier be installed between 1.5 m and 4 m from the road shoulder. This is because barriers placed any closer to the roadway lead to significant increases in collisions with the barrier and offset further away lead to increase in impact angle resulting in increased crash severity (Austroads 2014b).

Crash studies on the use of flexible safety barriers (wire-rope barriers) on a sample of high-speed Victorian roads reported a lower average crash severity than other barrier types or roadside hazards Austroads (2014c). Flexible barriers have been found to significantly reduce the severity of crash outcomes (all injury and serious injury crashes).

Crash reduction potentials of barriers as reported in the literature include the following:

- 32% - change rigid barrier to less rigid type (Austroads 2014d)
- 40 - 60% of all injury crashes due to installing barriers (iRAP 2014)
- 56% reduction in fatal crashes, 23% reduction of injury crashes and 30% reduction in all crashes due to the installation of new guardrails (Arizona Department of Transport 2009),
- 79% to 85% reduction in all head-on and run-off-road injury crashes due to the installation of flexible barriers (Candappa et all 2009)
- 83% to 87% reduction in head-on and run-off-road serious injury crashes due to the installation of flexible barriers (Candappa et all 2009)

All barrier types are hazardous to motorcyclists with a high risk of sustaining serious injury or death from sliding into or colliding with the barrier. Barrier systems can be made more motorcycle friendly by shielding the barrier posts, modifying or replacing posts with more forgiving post shapes or covering exposed posts with specifically designed impact attenuators (Austroads 2014b).

Horizontal alignment improvement

There are several ways in which the horizontal alignment of a roadway may be modified to improve safety. These include increasing the radius, providing transition curves between the straight and the bend, eliminating compound curves, improving superelevation and curve lane widening to assist vehicles tracking in their own lane (Austroads, 2014d).

The Austroads (2014d) provides crash risk reduction potential for horizontal alignment improvement and reconstruction of superelevation on a curve for run-off-road crashes of 10 to 50%.

Vertical alignment

Vertical realignments include reduction of the grade, increasing the radius of the crest for adequate sight distance and minimising the vertical acceleration changes (Austroads, 2014d). iRAP (2014) indicates a 10-25% crash reduction for vertical realignment.

Curve warning signs

Signs can be used to provide drivers with advanced warning of a curve, or multiple curves ahead. Austroads (2009) indicates a 30% crash reduction of run-off-road crashes for the installation of curve warning signs.

Lane width

Austroads (2010d) recommends a 3.5 m lane width; however on low speed roads a 3.0 m lane is permitted when truck traffic is kept to a minimum, and the alignment and road safety history (for existing roads) are satisfactory. As reported in Section 2.2.3 Austroads (2014a) reported a benefit in lane widening for lane widths less than 3.5 m.

Sealed shoulder

The provision of a wider, sealed shoulder provides a greater area for errant vehicles to recover and hence contribute in reducing the incidence of run-off-road crashes (Peng et al 2012).

An Austroads assessment of the role of shoulders on crashes compared run-off-road casualty crash rates for rural undivided roads (100 km/h speed limit) in Victoria and reported the following findings (Austroads 2011):

- A combination of sealed and unsealed shoulder width increased the chance of successful recovery during a run-off-road event. The greatest reduction in crash rates was observed for roads with sealed shoulders complemented by unsealed shoulders.
- It was found that an extra 0.5–1.0 m width of unsealed shoulders had a potential to reduce run-off-road casualty crash rates by 35–50%.
- Sealed shoulder of at least 0.6–1.0 m was observed to reduce run-off-road casualty crash rates by 33–64% when compared with similar roads with unsealed shoulders only.

This data was re-analysed by Austroads (2014c) and it showed that the high crash risk for a narrow seal (lane width and sealed shoulder widths less than 3 m) can be substantially reduced by the provision of wide unsealed shoulders.

Austroads (2014d) provides run-off-road casualty crash reductions of:

- 30% for sealing existing unsealed shoulder (0.6-1.0 m)

- 44% for 0.5 m sealed shoulder (where none existed previously)
- 72% for 1.0 m sealed shoulder (where none existed previously)
- 76% for 1.5 m sealed shoulder (where none existed previously)

Edge line treatments

Profile edge lining, including shoulder rumble strips and audio tactile edge lines, consist of series of grooves or raised strips placed along the road shoulder. When a driver passes over these it generates a vibration or noise to alert the driver to move back into their lane. Austroads (2012) derived a crash reduction of 20% for all casualty crashes and a 40% reduction for run-off-road crashes for the installation of profile edge lines. The use of shoulder rumble strips in the urban environment may not be desirable to cyclists and may produce increased noise levels.

Austroads (2009) indicates the provision of edge lines reduced the incidence of run-off-road crashes by 30%, while other types of delineation measures (i.e. guide posts, centreline road markings and RRPMs) reduced run-off-road crashes by 15%. Austroads (2012) provides a crash reduction factor of 10% for all casualty crashes for the provision of standard edge lines

Sight distance

Austroads (2012) reported a 30% reduction for all casualty crashes for the improvement of sight distance in a rural environment.

Chevron alignment markers

Chevron alignment markers (CAMs) are often used on bends either in association with advanced warning sign or on their own. Austroads (2012) derived a crash reduction factor of 25% for all casualty crashes for the installation of CAMs.

Impact attenuators

Impact attenuation does not influence the incidences of crashes but impacts on the severity of crashes. Austroads (2012) provides casualty crash reduction of 50% and fatal crash reduction of 70% for the installation of impact attenuators.

Austroads (2014b) reported that the installation of impact attenuators resulted in a 45% reduction of run-off-road crashes and 69% reduction in fixed object fatality crashes.

2.3.4 Vehicle Technology and Design

Run-off-road crashes are mostly associated with human-related factors (Peng 2012). Hence vehicle technology and design improvements that help reduce the likelihood of these errors occurring would help reduce driver leaving the travelled way. A list of these vehicle safety features that may assist in the reduction of run-off-road crashes are discussed in Section 2.2.4.

2.4 Review of TMR Strategies

A number of priority actions are listed in the Queensland Road Safety Action Plan 2013-2015 to address high risk sites on the state-controlled road network. Available funding programs include the Safer Roads Sooner, Black Spot and Road Safety Minor Works programs. There are specific items within the Safer Roads Sooner budget which specifically address run-off-roads and head-on crashes including wide centreline treatment mass action program, roadside hazard mass action program, and barrier end treatment mass action programs. Projects specifically related to head-on and run-off road crashes include:

- Installing wide centreline road markings including audio tactile line marking to reduce the likelihood of head-on crashes
- Removing roadside hazard removal, installing safety barriers and sealing shoulders to reduce likelihood and severity of run-off road crashes.

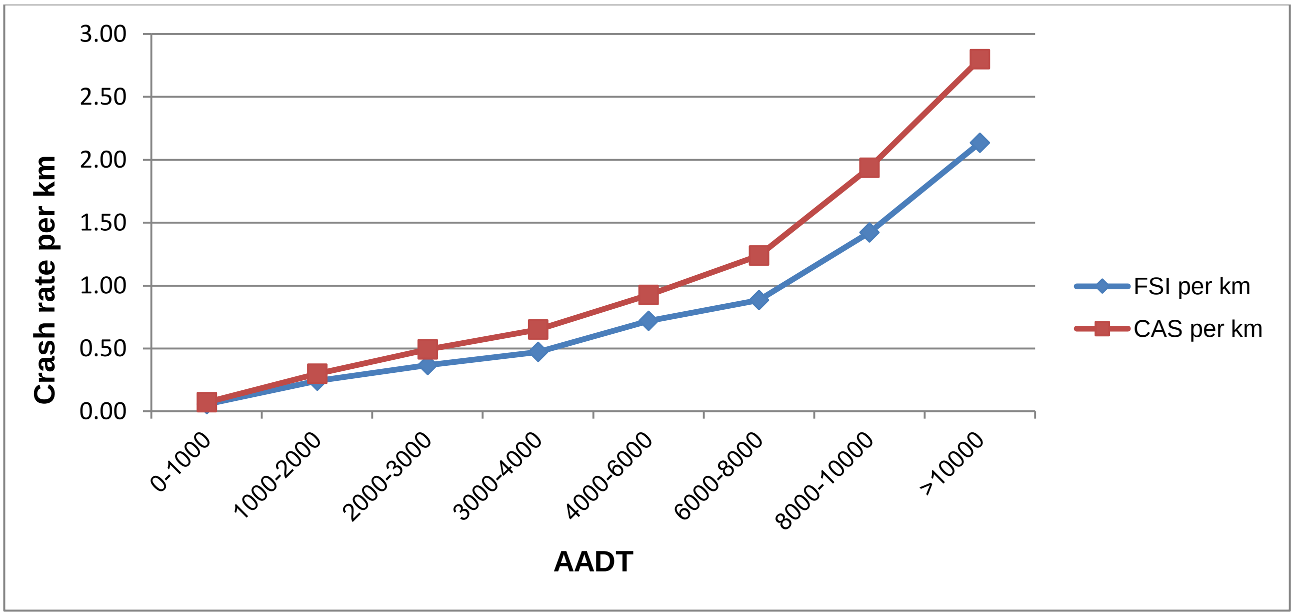
Due to budget constraints TMR have developed a methodology to identify and prioritise projects to be completed under these funding programs. The criteria for identifying and selecting high risk routes for the wide centreline treatment (WCLT) mass action program (on non-Bruce Highway sites) are based on:

- speed equal to or greater than 70km/h
- sealed width of at least 10 metres
- AADT greater than 3,500 vehicles per day (based on crash rate vs AADT relationship, Figure 2.1)
- Head-on and run-off-road crashes

The 3500 AADT cut-off value implies crashes on roads carrying traffic volume less than 3500 are not catered for. This will be an issue if the crashes on these low volume roads that are excluded comprised substantial proportion of the crashes on the network.

For high order roads such as Bruce Highway the suggested AADT criteria for selecting sites for installing WCLT is 2000 or more.

Figure 2.1: AADT and crash rate relationship



2.5 Summary of Findings

A summary of the engineering treatments determined from the literature review, which may be implemented to reduce the incidence of or severity of head-on and run-off-road crashes is provided in Table 2.1. The table provides the effectiveness of the treatment, an indication of the cost and the treatment life.

Table 2.1: Summary of treatment and their effectiveness

Treatment	Crash Type	Effectiveness (crash reduction factor)	Cost (high, medium, low)	Treatment Life
Horizontal alignment – increasing curve radius	All casualty	10-50%	high	20 years +
Reconstruction of superelevation	Head-on & run-off-road	50%	High	20 years +
Vertical realignment	All casualty	10-25%	High	20 years +
Installation of curve advanced warning signs	Head-on & run-off-road	30%	Low	5-10 years
Lane widening	All casualty	5-19%	Medium to High	5-10 years
Sealing of road shoulder	Head-on Run-off-road	40% 35-80%	Medium	5-10 years
Improving Sight distance	All casualty	30%	Low to High	5-10 years
Provision of overtaking lanes	Head-on	30%	High	10 years +
Installation of traffic calming	All casualty	20%	High	10 years +
Road duplication	Head-on	90%	High	20 years
Installation of centrelines	All casualty	20%	Low	1-5 years
Wide centrelines*	Head-on	75% (fatal crashes)* 59% (FSI crashes)*	Low	1-5 years
Painted median	All casualty	10-25%	Low	1-5 years
Profiled centreline	Head-on	30%	Low	1-5 years
Improved skid resistance	All casualty	Urban 35%	Low to medium	5-10 years
Flexible Safety barriers	Run-off-road & head-on	79-87% (all injuries) 79-87% (serious injuries)	Medium	10-20 years
Semi rigid safety barrier	Run-off-road	30% (all crashes) 23% (injury crashes) 56% (fatal crashes)	Medium	10-20 years
Rigid safety barrier	All crash types	-15%	Medium	10-20 years
Impact attenuators	Run-off-road Fixed object	45% 69%	Medium	10-20 years
Chevron alignment markers	All casualty	25%	Low	1-5 years
Profile edge lines	Run-off-road	40%	Low	1-5 years
Standard edge lines	Run-off-road	30%	Low	1-5 years

* - These values (considered too high) are based on a limited dataset over a short period from a single study. An-going study using data set from a much longer period will confirm or provide updated values.

3 CRASHES ANALYSIS

3.1 Crash Data

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

- Fatal crashes from January 2007 to 31 May 2014
- Hospitalisation crashes from January 2007 to 31 December 2013
- Medical treatment and minor injury crashes from January 2007 to 31 December 2011
- Property Damage Only crashes (PDOs) from January 2007 to 31 December 2010

The latest five years of injury crash data (from 2007 to 2011) has been analysed. This included minor injury, medical treatment, hospitalisation and fatal crashes. PDO crashes have been excluded from this data analysis.

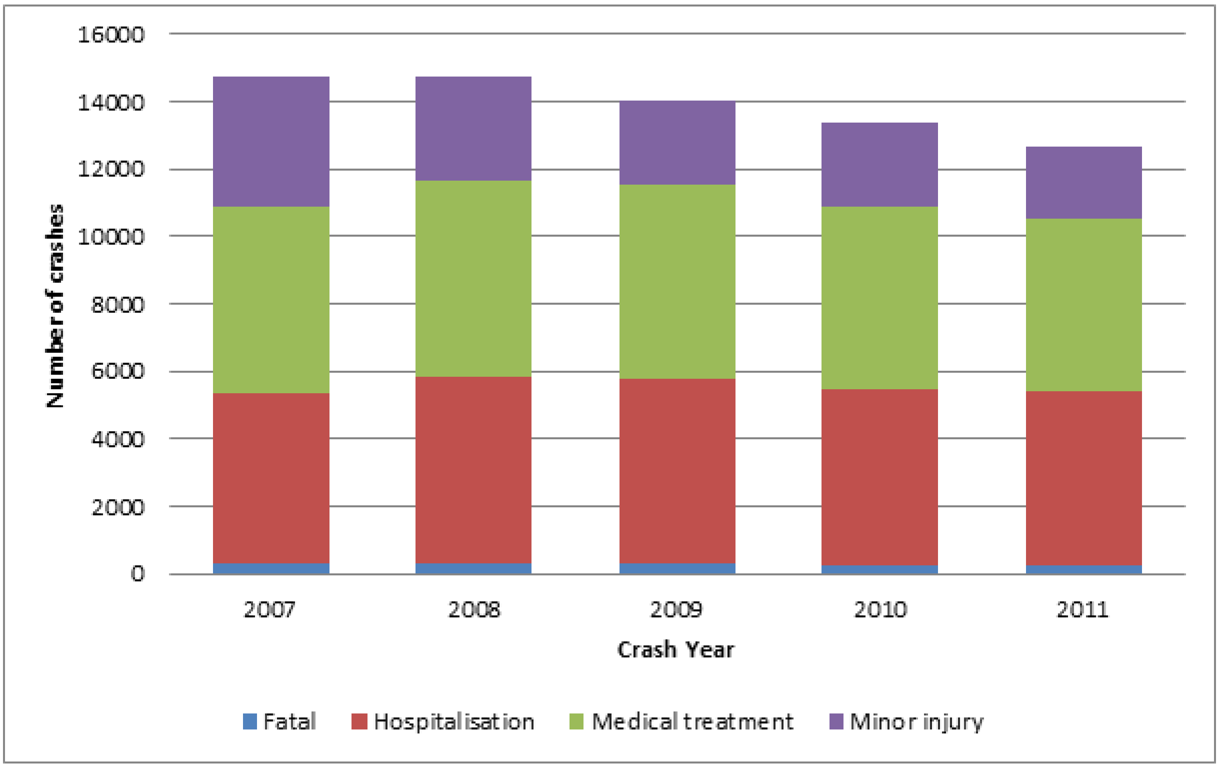
3.2 Queensland Injury Crashes

3.2.1 Annual Crashes

Between 2007 and 2011, there were a total of 69 533 injury crashes recorded on Queensland roads, of which 27 877 (approximately 40%) resulted in fatal or serious injury (FSI).

Figure 3.1 shows that the number of injury crashes gradually reduced after the peak in 2008. The number of FSI crashes consisting of fatal and hospitalisation crashes also peaked in 2008 at 5 821 and gradually reduced to 5 432 in 2011.

Figure 3.1: Injury crashes by year and severity (2007-11)



3.2.2 Injury Crashes by Road Authorities

Figure 3.2 shows that more injury crashes occurred each year on locally controlled roads (52%) than on state-controlled roads (48%). However, the proportion of fatal crashes was slightly higher on state-controlled roads (3%) than locally controlled roads (2%) as shown in Figure 3.3.

Figure 3.2: Injury crashes by year and road authorities (2007-11)

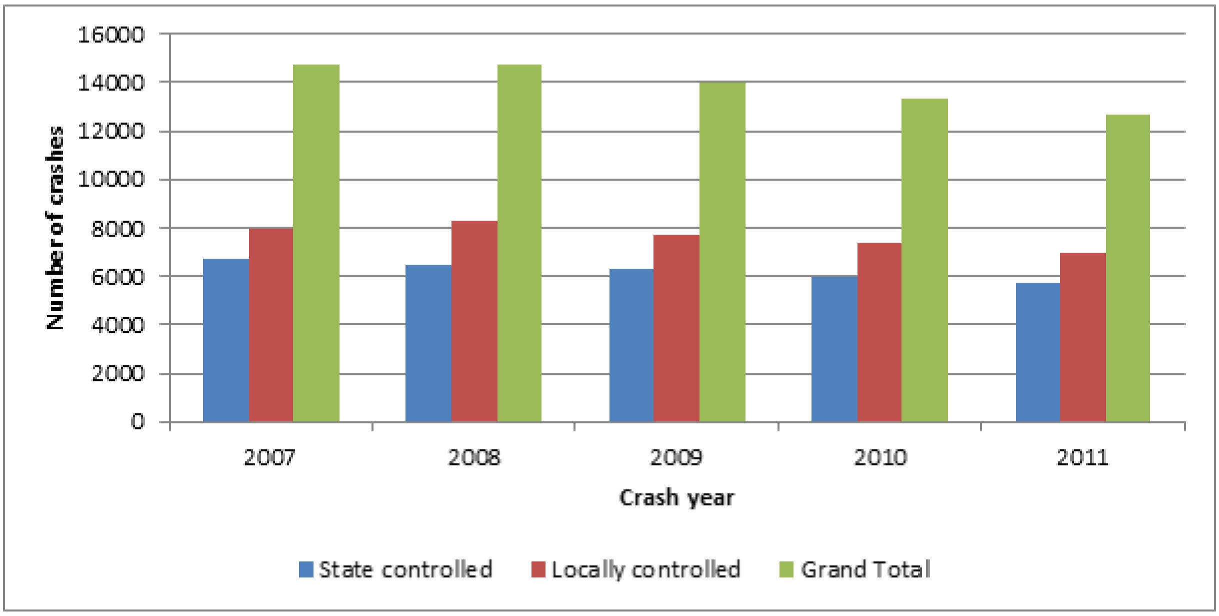
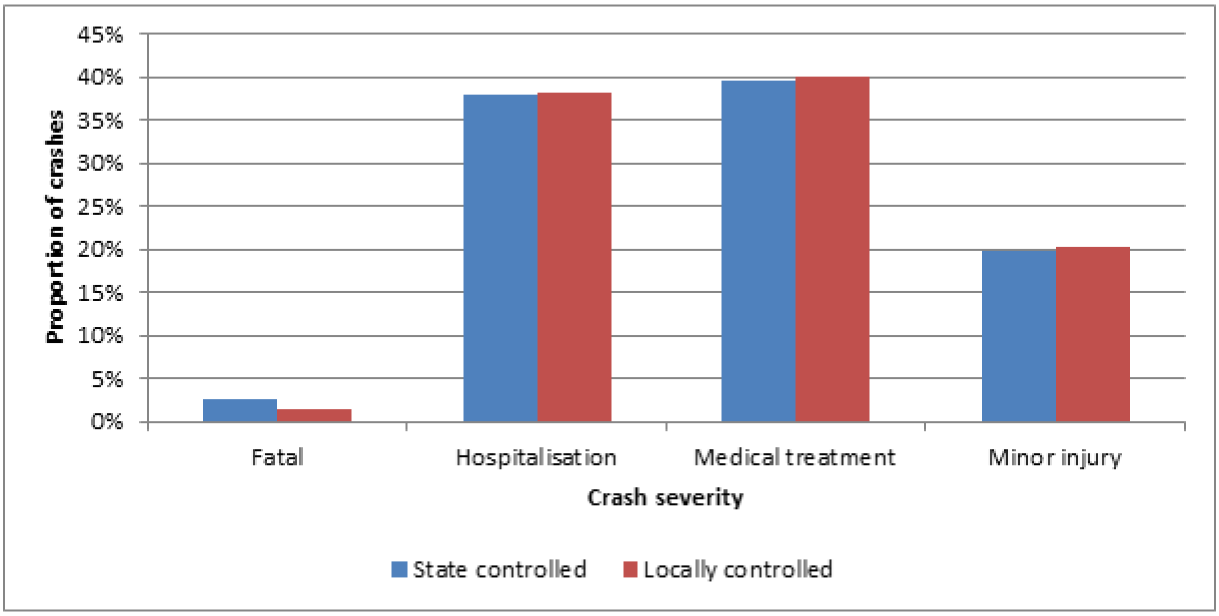


Figure 3.3: Injury crashes by road authorities and severity (2007-11)



3.2.3 Injury Crashes by DCA Groups

Table 3.1 shows the number and proportion of injury crashes by DCA groups. The results indicate that:

- rear-end crashes accounted for 23% of all injury crashes - a large proportion (38%) of these rear-end crashes were found to have occurred at intersections
- intersection crashes accounted for 43% of all injury crashes and 40% of FSI crashes
- head-on crashes accounted for 4% of all injury crashes and 6% of FSI crashes
- run-off-road crashes accounted for 21% of all injury crashes and 27% of FSI crashes
- out-off-control crashes on carriageway accounted for 5% of all injury crashes and 6% of FSI crashes.

Table 3.1: Injury crashes by DCA code (2007-11)

DCA Code	Description	Classification	Number of injury crashes	Percentage of injury crashes (%)	FSI	FSI (%)
0	Other	Pedestrian	556	0.8%	297	1.1%
1	Near side	Pedestrian	1212	1.7%	669	2.4%
2	Emerging	Pedestrian	203	0.3%	114	0.4%
3	Far side	Pedestrian	1038	1.5%	629	2.3%
4	Playing, working, lying, standing on carriageway	Pedestrian	441	0.6%	246	0.9%
5	Walking with traffic	Pedestrian	136	0.2%	79	0.3%
6	Facing traffic	Pedestrian	53	0.1%	33	0.1%
7	Driveway	Pedestrian	74	0.1%	20	0.1%
8	On footway	Pedestrian	22	0.0%	8	0.0%
9	Struck while boarding or alighting	Pedestrian	101	0.1%	60	0.2%
100	Other	Intersection	290	0.4%	120	0.4%
101	Through-through	Intersection	4410	6.3%	1698	6.1%
102	Right-through	Intersection	561	0.8%	199	0.7%
103	Left-through	Intersection	132	0.2%	57	0.2%
104	Through-right	Intersection	3845	5.5%	1504	5.4%
105	Right-right	Intersection	147	0.2%	40	0.1%
106	Left-right	Intersection	117	0.2%	37	0.1%
107	Through-left	Intersection	748	1.1%	253	0.9%
108	Right-left	Intersection	3	0.0%	1	0.0%
109	Left-left	Intersection	12	0.0%	4	0.0%
200	Other	Other	187	0.3%	79	0.3%
201	Head-on	Head-on	2480	3.6%	1492	5.4%
202	Through-right	Intersection	6184	8.9%	2616	9.4%
203	Right-left	Intersection	58	0.1%	18	0.1%
204	Right-left	Intersection	21	0.0%	6	0.0%
205	Through-left	Intersection	18	0.0%	9	0.0%
206	Left-left	Intersection	0	0.0%	0	0.0%

DCA Code	Description	Classification	Number of injury crashes	Percentage of injury crashes (%)	FSI	FSI (%)
207	U turn	U turn	256	0.4%	95	0.3%
300	Other	other	188	0.3%	69	0.2%
301	Rear end	Rear end	11802	17.0%	2720	9.8%
302	Left rear	Rear end	1959	2.8%	255	0.9%
303	Right rear	Rear end	2684	3.9%	742	2.7%
304	U turn	U turn	102	0.1%	22	0.1%
305	Lane side swipe	Side swipe	967	1.4%	361	1.3%
306	Lane change right	Lane change	523	0.8%	146	0.5%
307	Lane change left	Lane change	680	1.0%	202	0.7%
308	Right turn side swipe	Side swipe	927	1.3%	326	1.2%
309	Left turn side swipe	Side swipe	469	0.7%	154	0.6%
310	Pulling out	Side swipe	0	0.0%	0	0.0%
400	Other	Manoeuvring	916	1.3%	369	1.3%
401	Leaving parking	Manoeuvring	184	0.3%	38	0.1%
402	Parking	Manoeuvring	110	0.2%	33	0.1%
403	Parking vehicles only	Manoeuvring	30	0.0%	6	0.0%
404	Reversing in traffic	Manoeuvring	69	0.1%	13	0.0%
405	Reversing into fixed object	Manoeuvring	46	0.1%	15	0.1%
406	Leaving driveway	Manoeuvring	1364	2.0%	470	1.7%
407	From loading bay	Manoeuvring	0	0.0%	0	0.0%
408	From footway	Manoeuvring	1172	1.7%	464	1.7%
500	Other	Overtaking	77	0.1%	36	0.1%
501	Head-on due to overtaken	Head-on	76	0.1%	56	0.2%
502	Out-of-control due to overtaking	Overtaking	209	0.3%	118	0.4%
503	Pulling out	Overtaking	22	0.0%	10	0.0%
504	Cutting in	Overtaking	24	0.0%	11	0.0%
505	Pulling out rear end	Overtaking	33	0.0%	13	0.0%
506	Overtaking right turn	Overtaking	298	0.4%	129	0.5%
600	Other	On path	153	0.2%	75	0.3%
601	Parked	On path	703	1.0%	291	1.0%
602	Double parked	On path	1	0.0%	1	0.0%
604	Car door	On path	96	0.1%	37	0.1%
605	Hit permanent obstruction	On path	25	0.0%	10	0.0%
606	Hit temporary roadwork	On path	10	0.0%	1	0.0%
607	Hit temporary object on carriageway	On path	950	1.4%	409	1.5%
608	Accident or broken down	On path	103	0.1%	52	0.2%
609	Animal	On path	508	0.7%	240	0.9%
610	Load hit vehicle	On path	105	0.2%	32	0.1%
700	Other		909	1.3%	446	1.6%

DCA Code	Description	Classification	Number of injury crashes	Percentage of injury crashes (%)	FSI	FSI (%)
701	Off carriageway to left	Run-off-road	472	0.7%	236	0.8%
702	Off Carriageway to right	Run-off-road	350	0.5%	185	0.7%
703	Left off carriageway into object	Run-off-road	3652	5.3%	1798	6.4%
704	Right off carriageway into object	Run-off-road	1771	2.5%	909	3.3%
705	Out of control on carriageway	Out-of-control	1727	2.5%	900	3.2%
706	Left turn	Run-off-road	148	0.2%	77	0.3%
707	Right turn	Run-off-road	143	0.2%	64	0.2%
708	Mounts traffic island	Run-off-road	689	1.0%	355	1.3%
800	Other	Run-off-road	669	1.0%	315	1.1%
801	Off carriageway right bend	Run-off-road	484	0.7%	234	0.8%
802	Off carriageway left bend	Run-off-road	362	0.5%	195	0.7%
803	Off right bend into object	Run-off-road	2622	3.8%	1400	5.0%
804	Off left bend into object	Run-off-road	1946	2.8%	1030	3.7%
805	Out of Control on Carriageway	Out-of-control	1538	2.2%	826	3.0%
806	Left turn	Run-off-road	43	0.1%	22	0.1%
807	Right turn	Run-off-road	45	0.1%	23	0.1%
808	Mounts traffic island	Run-off-road	307	0.4%	160	0.6%
900	Other	Other	140	0.2%	71	0.3%
901	Fell in/from vehicle	Other	512	0.7%	265	1.0%
903	Hit train	Other	41	0.1%	29	0.1%
904	Hit railway crossing furniture	Other	15	0.0%	5	0.0%
905	Hit animal off carriageway	Other	3	0.0%	1	0.0%
906	Parked vehicle runaway	Other	52	0.1%	21	0.1%
907	Vehicle movements not known	Other	1	0.0%	0	0.0%

3.3 Head-on Crashes

A head-on crash event has been defined as ‘when a vehicle departs from its laneway into opposing traffic striking any portion of the leading edge of an opposing vehicle’. The DCA codes classified as head-on crash and included in the data analysis are shown in Table 3.2. Out of the 69,533 injury crashes reported on Queensland roads between 2007 and 2011, head-on crashes accounted for 4% of all injury crashes and 6% of FSI crashes. On state-controlled roads, head on crashes accounted for about 4% of all injury crashes and 7% of FSI crashes.

Only 3% of head-on crashes is due to overtaking vehicles. However, head-on collision due to overtaking (code 501) were more severe. About 74% of overtaking head-on collisions were FSI crashes compared to 60% for the other head-on type (code 201); and 21% of overtaking head-on collisions were fatal crashes compared to 11% for code 201 head-on collisions.

Table 3.2: Head-on crashes by DCA Code

DCA Code	Fatal	Hospitalisation	Medical treatment	Minor injury	Total
201	261	1231	667	321	2480 (97%)
501	16	40	9	11	76 (3%)
Total	277	1271	676	332	2556 (100%)

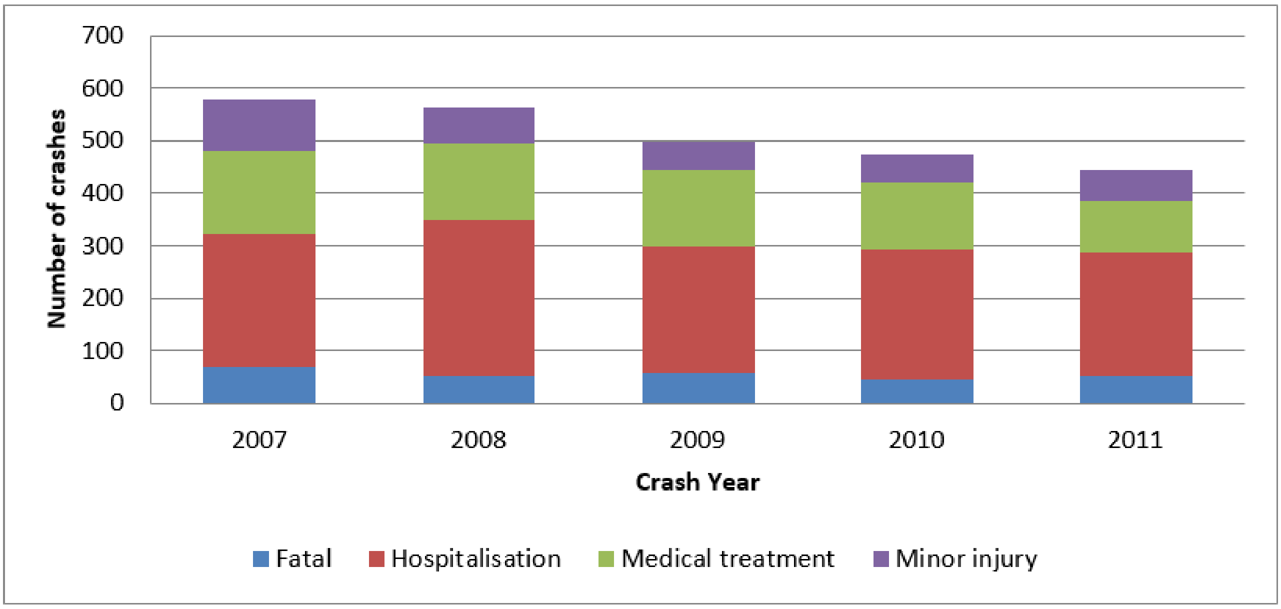
Notes

- DCA code 201 – head-on crash involving vehicles from opposing directions
- DCA code 501 – head-on crash due to overtaking

3.3.1 Annual Distribution of Head-on Crashes

Figure 3.4 shows the annual head-on injury crashes from 2007 to 2011. There has been a gradual decline in head-on injury crashes since 2007, an overall reduction of 23%. The FSI crash numbers peaked in 2008 at 348 crashes, and has decreased gradually since then. No such decline is observed in fatal head-on crashes.

Figure 3.4: Head-on injury crashes by year and severity (2007-11)



3.3.2 Head-on Injury Crash Severity

Figure 3.5 shows the severity of head-on injury crashes by road authority. Overall, 52% of the head-on injury crashes occurred on state-controlled roads. In addition, head-on injury crashes are more severe on state-controlled compared to locally controlled road. About 16% of the head-on injury crashes on state-controlled roads were fatal crashes, which is significantly higher than the 5% on locally controlled roads.

As shown in Figure 3.6, head-on crashes were more severe compared to all crash types. About 61% of head-on injury crashes resulted in fatalities or hospitalisation compared to the 40% for all injury crash types.

Figure 3.5: Head-on injury crashes by road authorities and severity (2007-11)

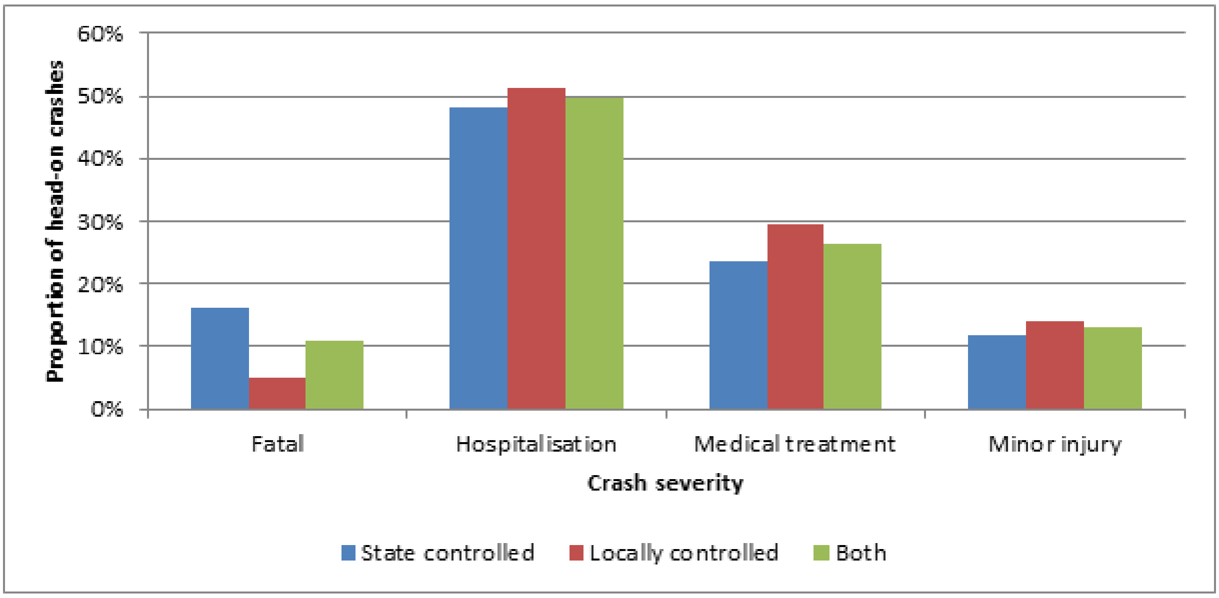
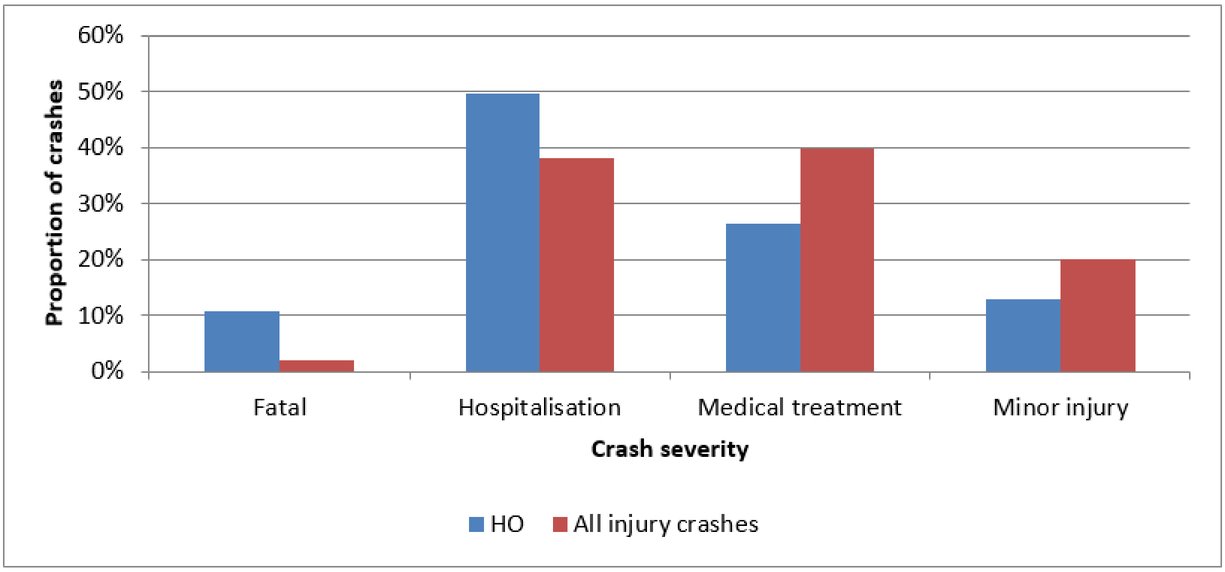


Figure 3.6: Crash severity comparison between head-on injury crashes and all injury crashes (2007-11)



3.3.3 Head-on Injury Crashes by Posted Speed Limit

Figure 3.7 and Figure 3.8 show the breakdown, by speed zone, of head-on injury crashes and all injury crashes, respectively. It is noted that:

- there are more head-on injury crashes (47%) on the high speed roads (80 km/h or more) compared to all injury crashes (27%).
- on state-controlled roads, 69% of head-on injury crashes occurred on high speed roads (80 km/h or more) compared to 45% on locally controlled roads
- most of the head-on injury crashes on locally controlled roads (72%) occurred on 0-60 km/h roads

Figure 3.7: Head-on injury crashes by posted speed limit (2007-11)

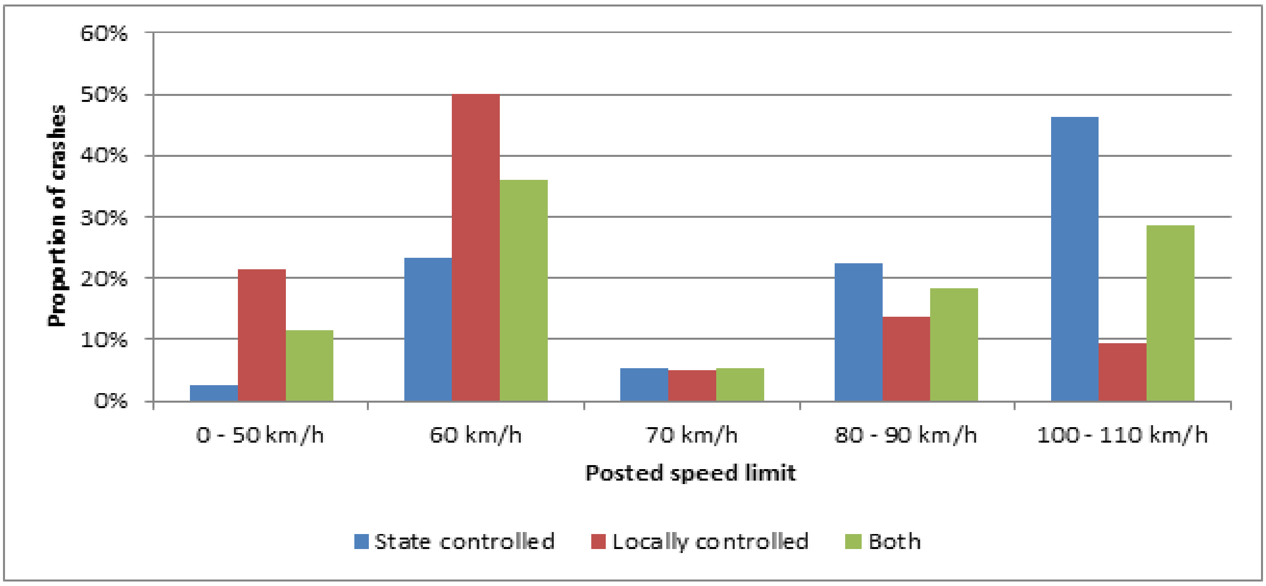
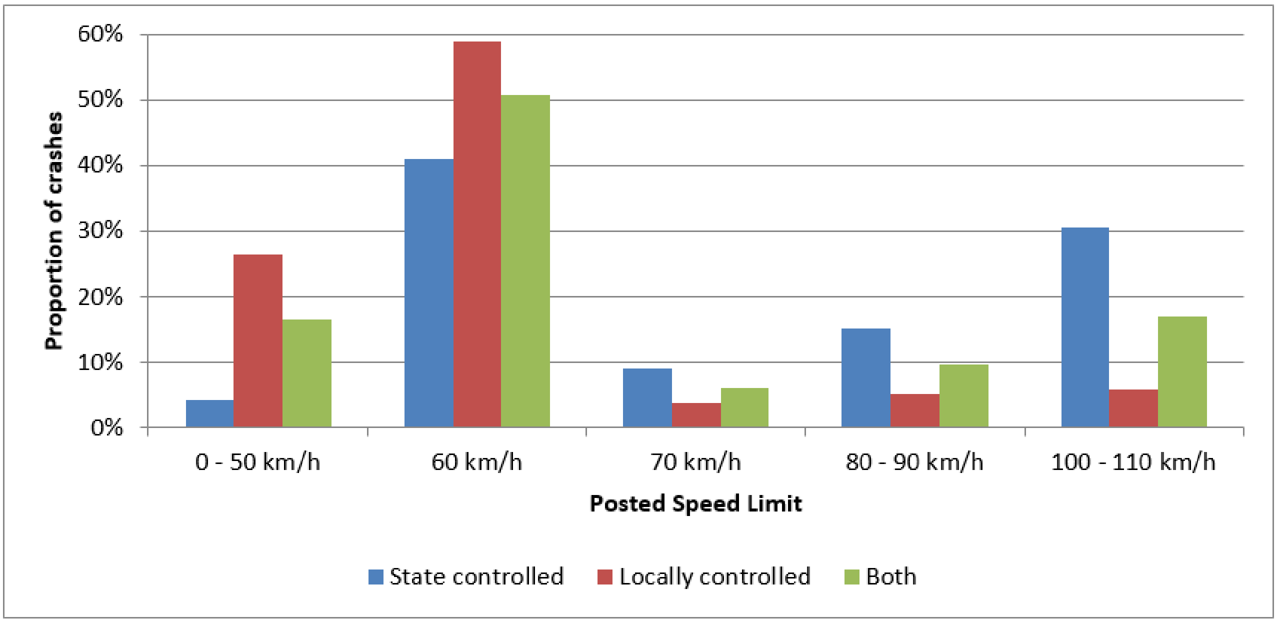
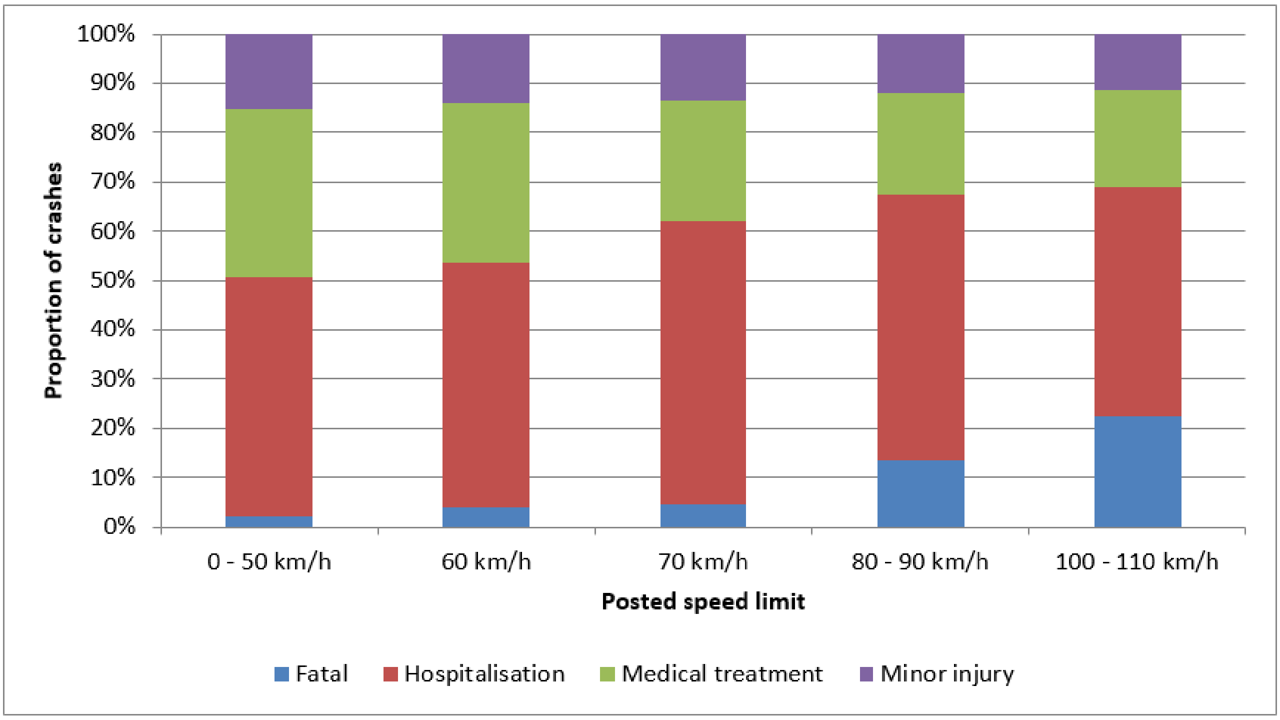


Figure 3.8: All injury crashes by posted speed limit (2007-11)



Severity of head-on crashes generally increased with the posted speed limit (Figure 3.9). Both fatal and FSI crashes due to head-on collision increased with increasing posted speed limit.

Figure 3.9: Head-on injury crashes by posted speed limit and severity (2007-11)



3.3.4 *Head-on Injury Crashes by Horizontal Alignment*

Figure 3.10 shows that 56% of head-on injury crashes occurred on curves (55% on state-controlled roads and 58% locally controlled roads). This is higher than the 23% for all injury crashes that occurred on curves (Figure 3.11). Since a large proportion of the network is made up of straight road sections, the data indicates a substantially higher risk for a head-on crash on a curve.

For all injury crashes, the proportion of FSI crashes was marginally higher on straight road sections than on curves (Figure 3.12).

Figure 3.10: Head-on injury crashes by horizontal alignment (2007-11)

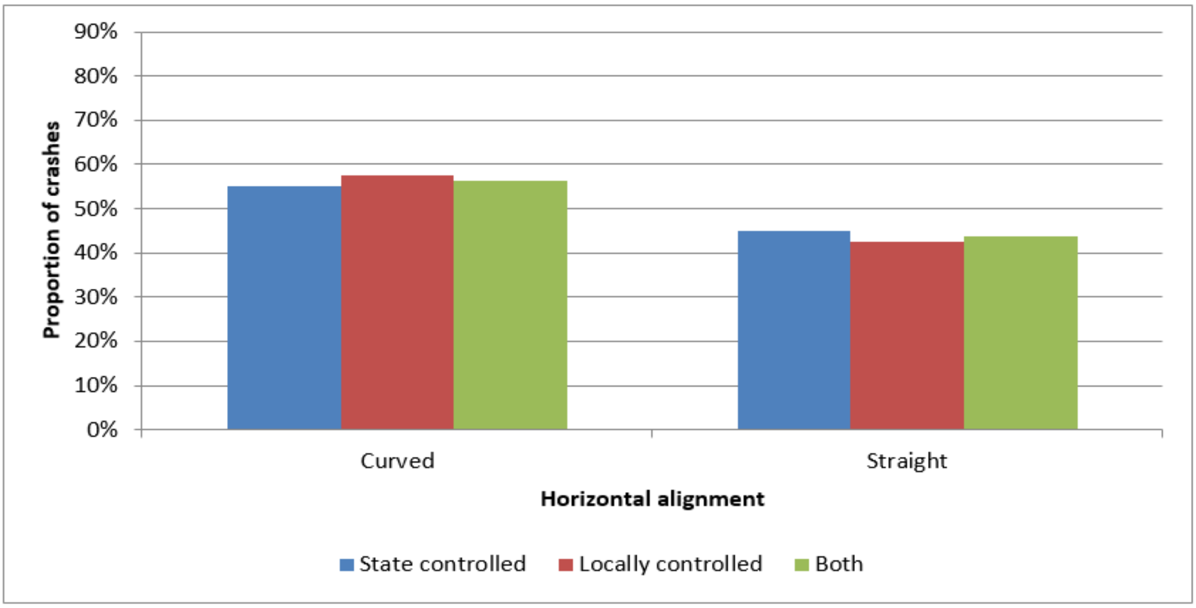


Figure 3.11: All injury crashes by horizontal alignment (2007-11)

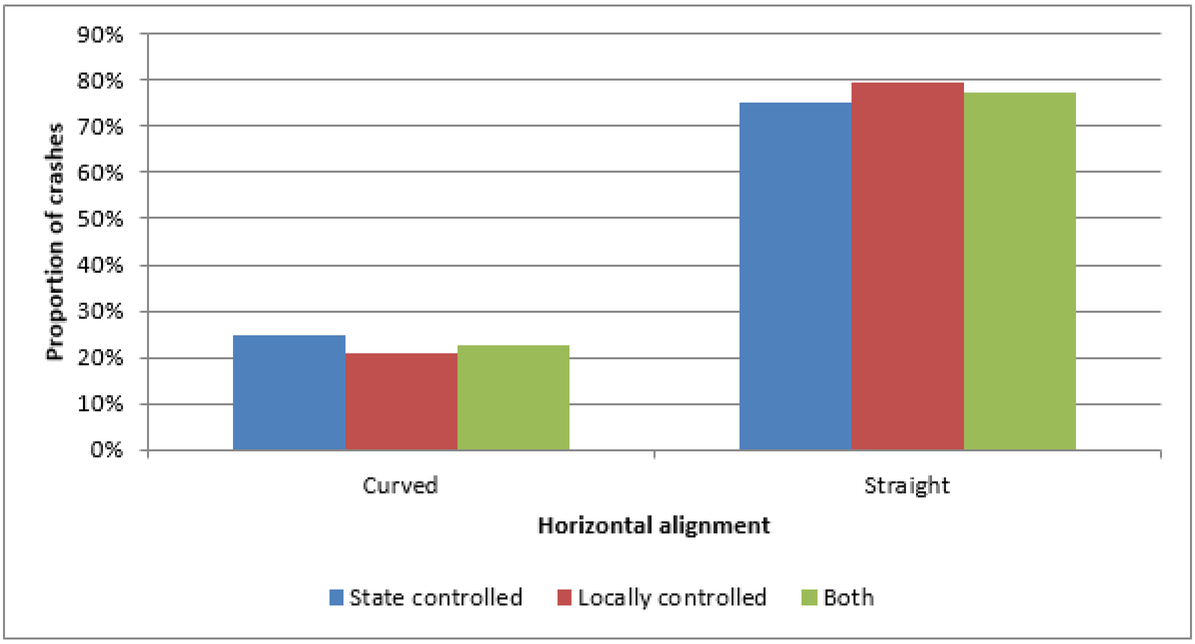
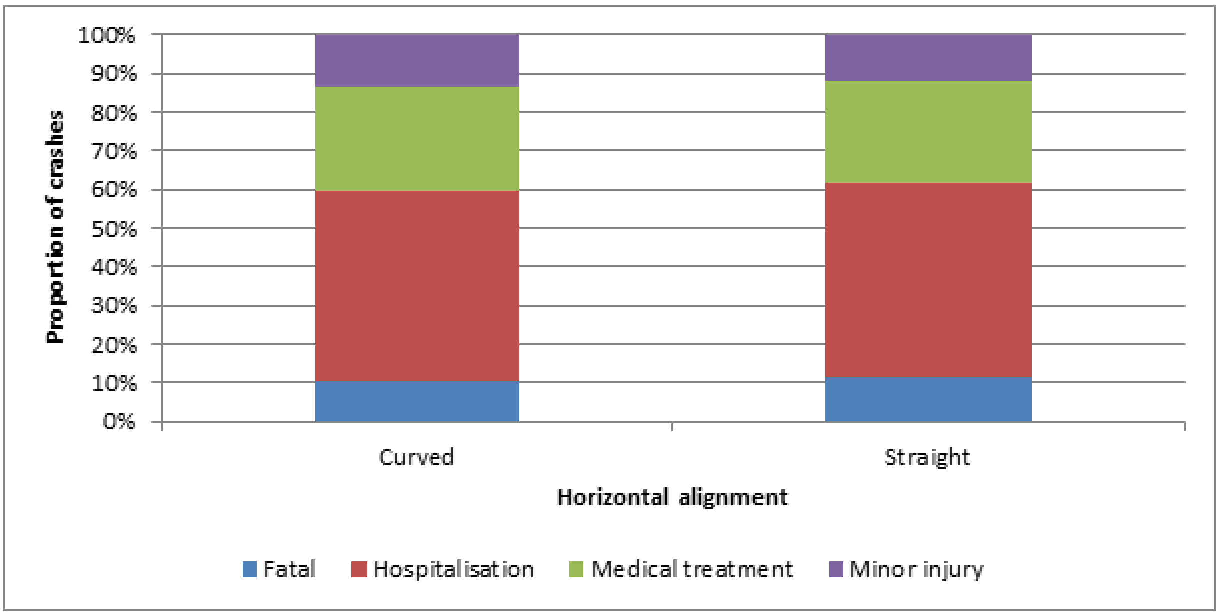


Figure 3.12: Head-on injury crashes by horizontal alignment and severity (2007-11)



3.3.5 Head-on Injury Crashes by Vertical Alignment

Figure 3.13 shows that 42% of head-on injury crashes occurred on a grade, dip or crest. This is significantly higher than the 25% for all injury crashes on Queensland roads that occurred on a crest, dip or grade (Figure 3.14).

Figure 3.15 shows that the proportion of FSI crashes were generally the same across the different vertical alignments. The risk of a fatal crash occurring is higher on grade and level ground compared to crest and dip sections.

Figure 3.13: Head-on injury crashes by vertical alignment (2007-11)

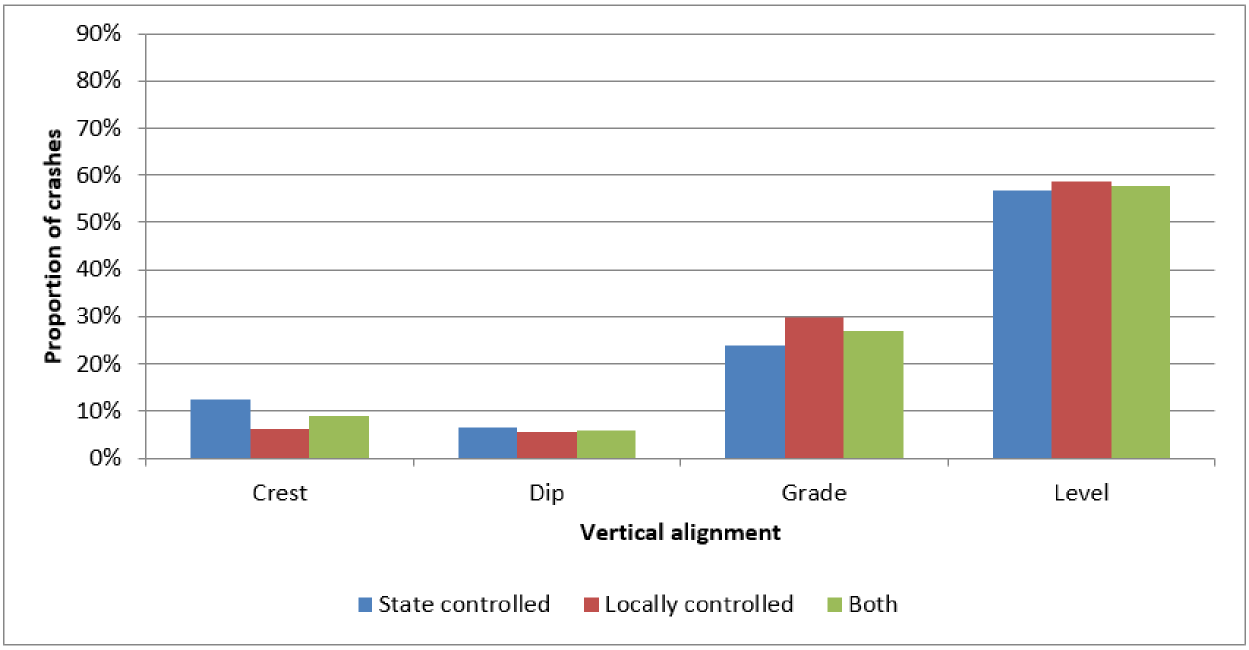


Figure 3.14: All injury crashes by vertical alignment (2007-11)

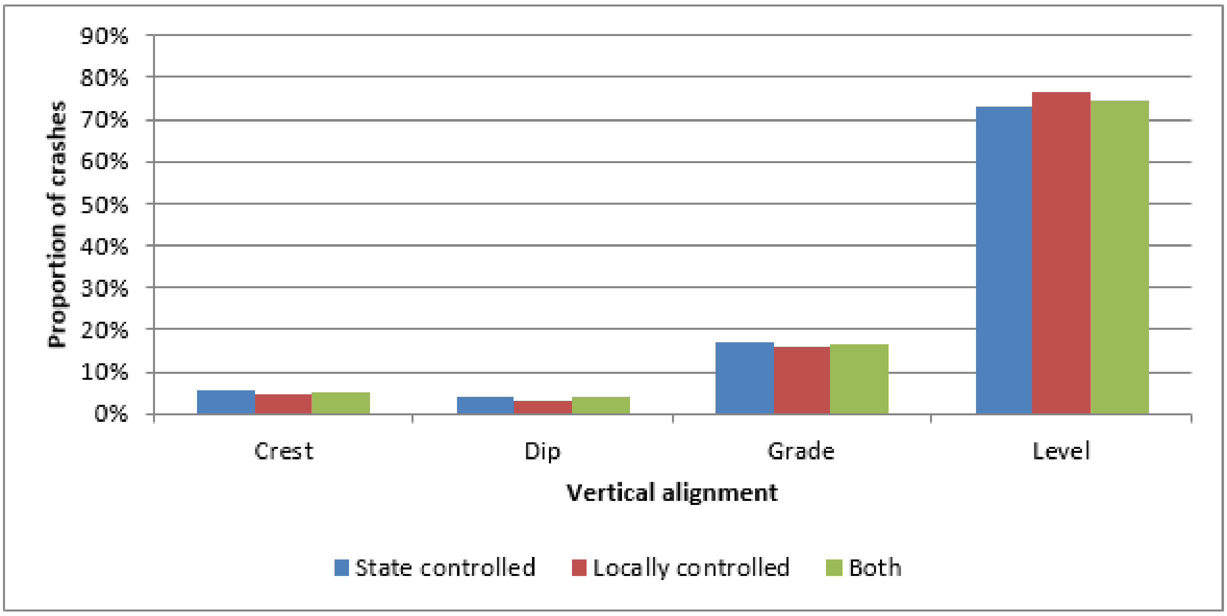
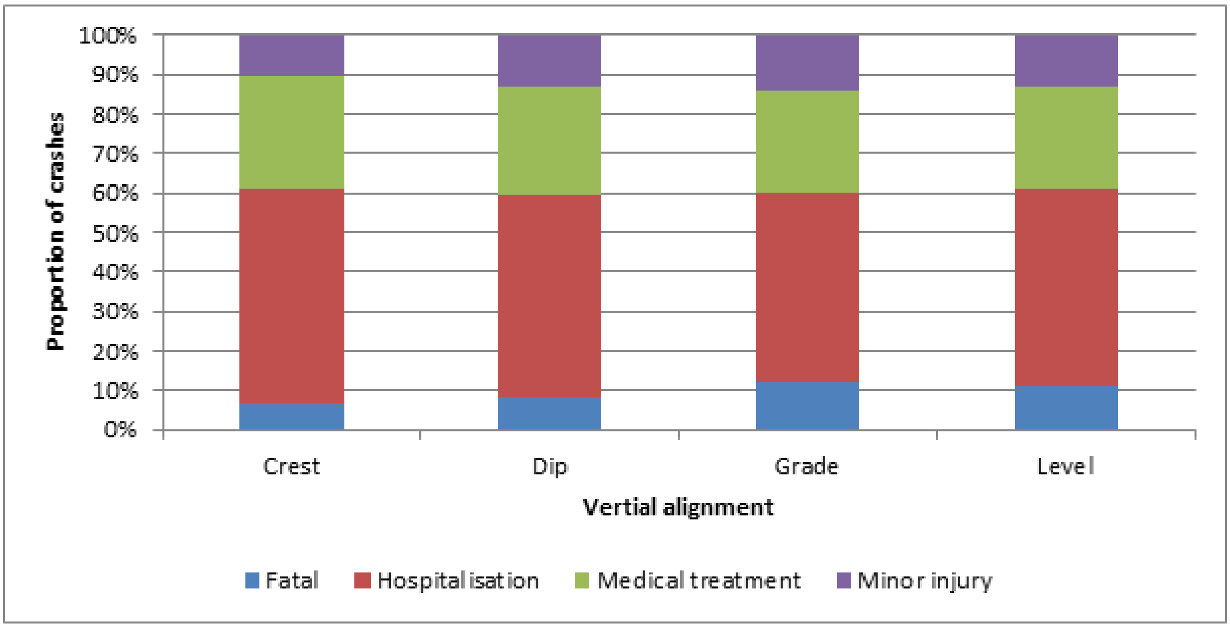


Figure 3.15: Head-on injury crashes by vertical alignment and severity (2007-11)



3.3.6 Head-on Injury Crashes by Road Surface Condition

Figure 3.16 shows the proportion of head-on injury crashes by road surface conditions. About 26% of head-on injury crashes occurred on a wet sealed road surface. This is higher than the 16% recorded for all injury crashes (Figure 3.17). Unsealed sections accounted for about 10% of the head-on injury crashes on locally controlled roads and about 2% on state-controlled roads (Figure 3.16). Combined 6% of head-on injury crashes occurred on unsealed roads, higher than for all injury crashes (3%).

Figure 3.16: Head-on injury crashes by road surface condition (2007-11)

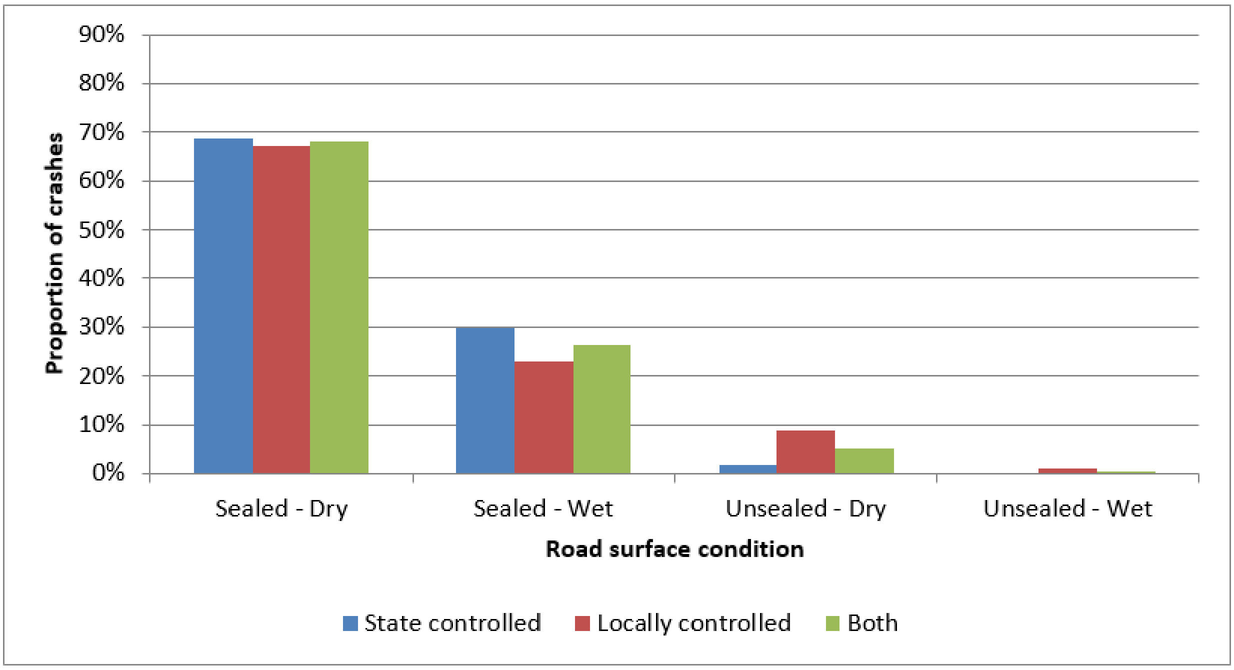


Figure 3.17: All injury crashes by road surface condition (2007-11)

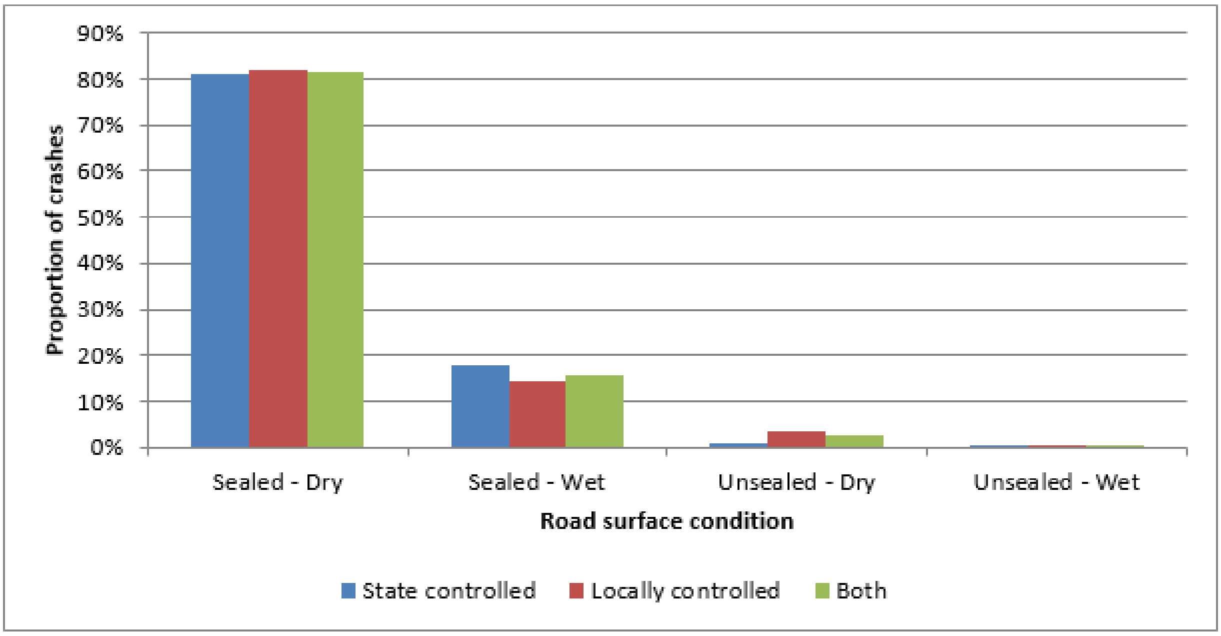
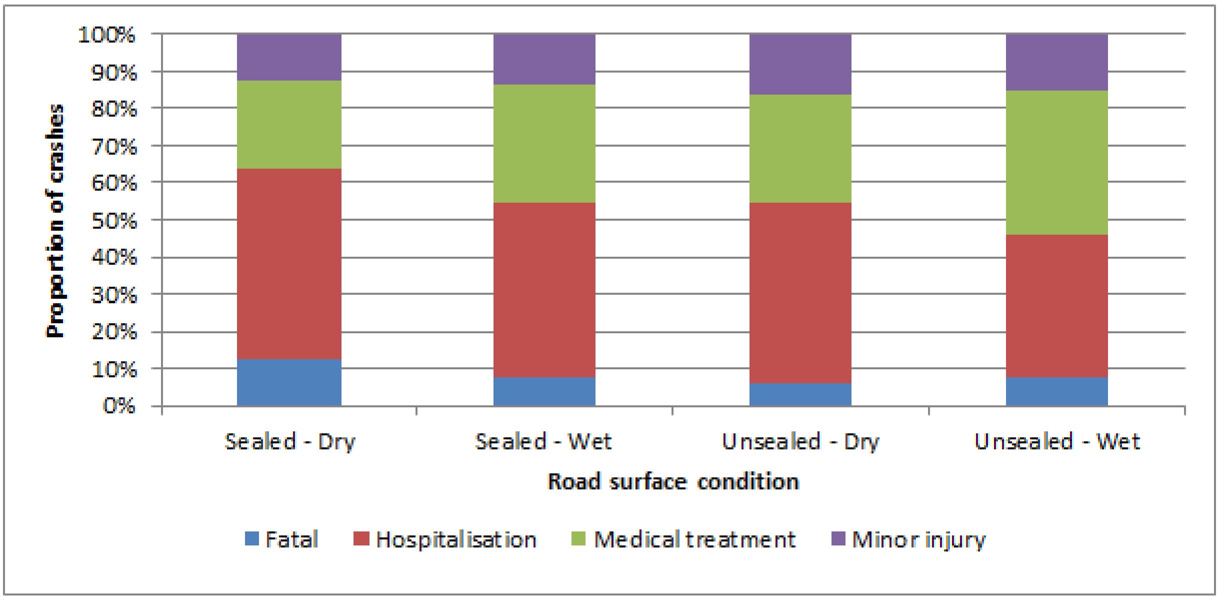


Figure 3.18 shows that head-on injury crashes that occurred on dry road surface had higher fatal and FSI proportions compared to those on wet road surface conditions. Head-on injury crashes on sealed roads also had higher fatal and FSI proportions compared to those on unsealed roads.

Figure 3.18: Head-on injury crashes by road surface condition and severity (2007-11)



3.3.7 Head-on Injury Crashes by Lighting Condition

Figure 3.19 shows the proportion of injury crashes by lighting conditions. About 29% of head-on injury crashes occurred during adverse lighting conditions (i.e. dark and dusk/dawn) on Queensland roads. This proportion is marginally lower than the 30% for all injury crashes (Figure 3.20).

Figure 3.19: Head-on injury crashes by lighting Condition (2007-11)

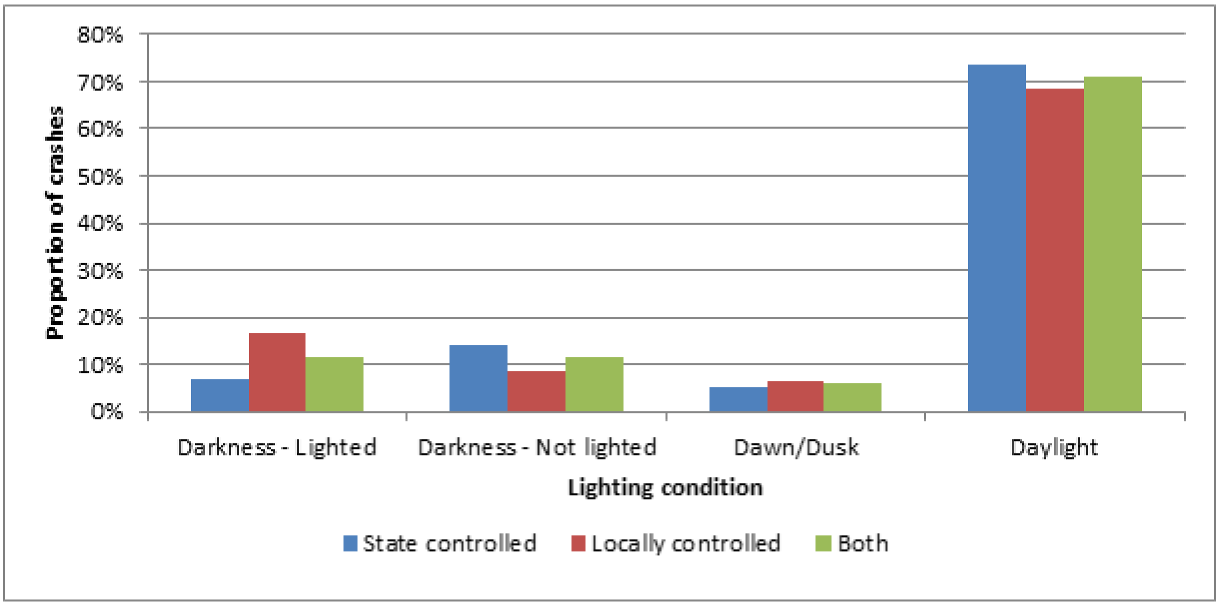


Figure 3.20: All injury crashes by lighting condition (2007-11)

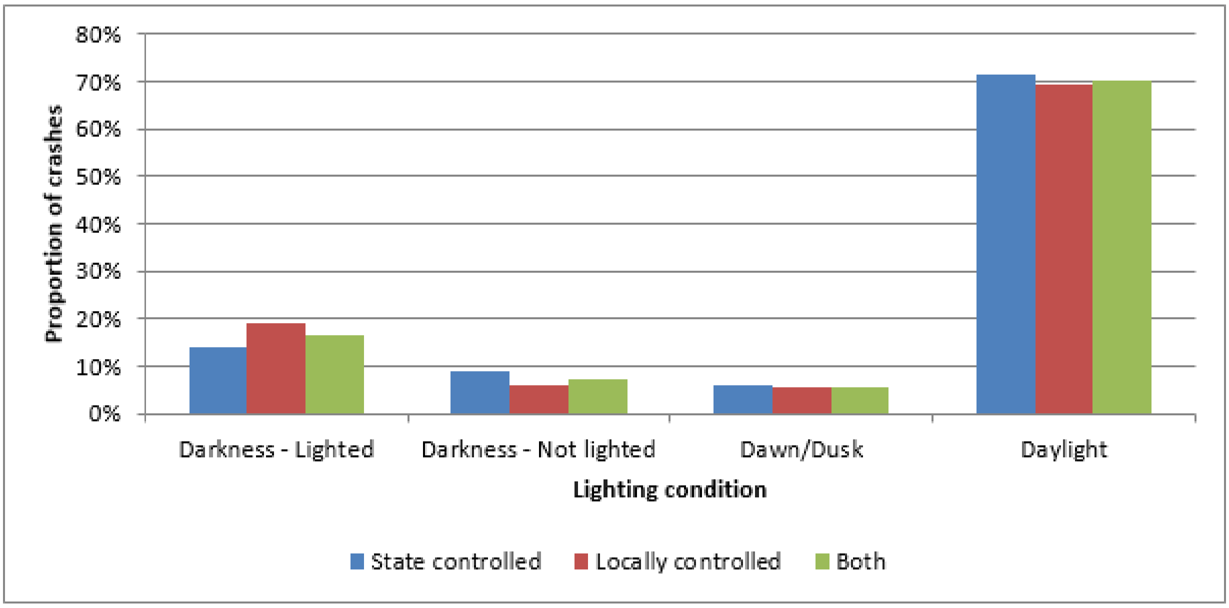
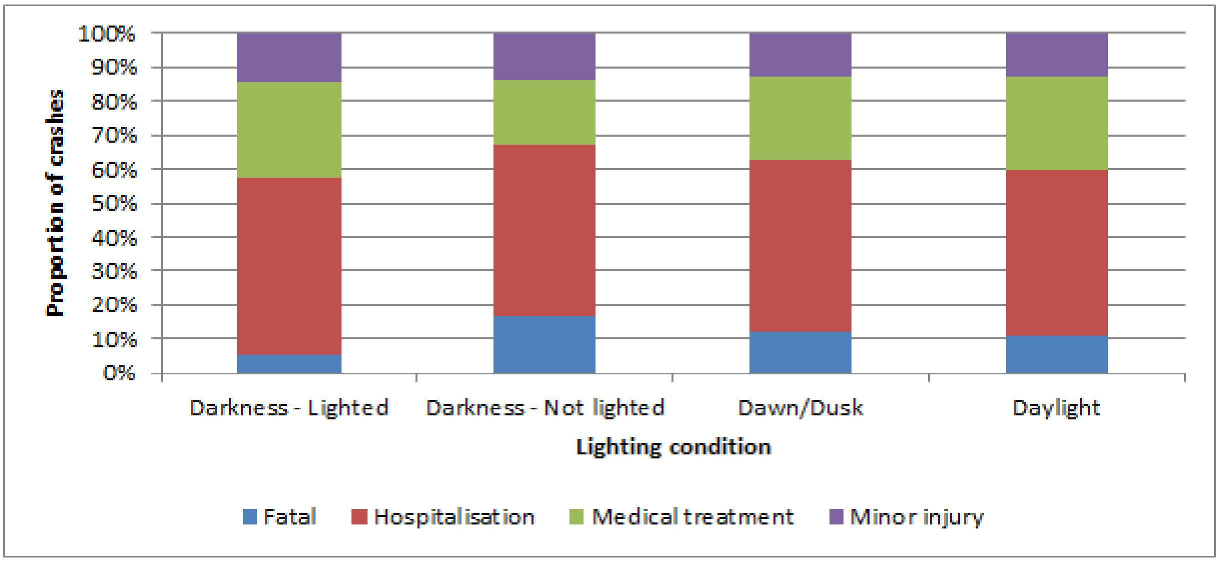


Figure 3.21 shows that crashes that occurred at night on roads with no street lighting accounted for the highest proportion of fatal crashes. While, darkness with street lighting condition recorded the lowest proportions of fatal crashes.

Figure 3.21: Head-on injury crashes by lighting condition and severity (2007-11)



3.3.8 *Head-on Injury Crashes by Time of Day*

Figure 3.22 shows that the peak for head-on injury crash occurred at 3 pm followed by a consistent decline, with the lowest crash numbers occurring between midnight and 4 am. About 15% of head-on injury crashes occurred between 7 pm and 6 am. The proportions of crashes during the morning peak (7-9 am) and evening peak (3-6 pm) were 9% and 24% respectively. The corresponding proportions for all injury crashes during the morning peak (7-9 am) and evening peak (3-6 pm) were 12% and 25% respectively (Figure 3.23). Thus the proportion of head-on injury crashes during the peak periods is slightly lower compared to all injury crashes.

Figure 3.22: Head-on injury crashes by time of day (2007-11)

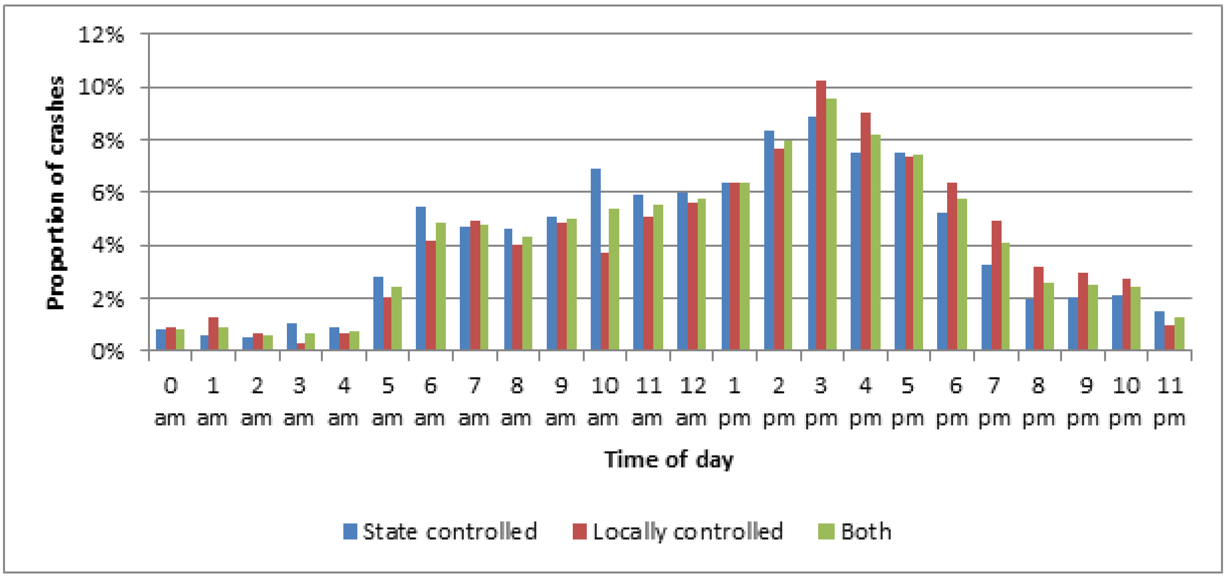
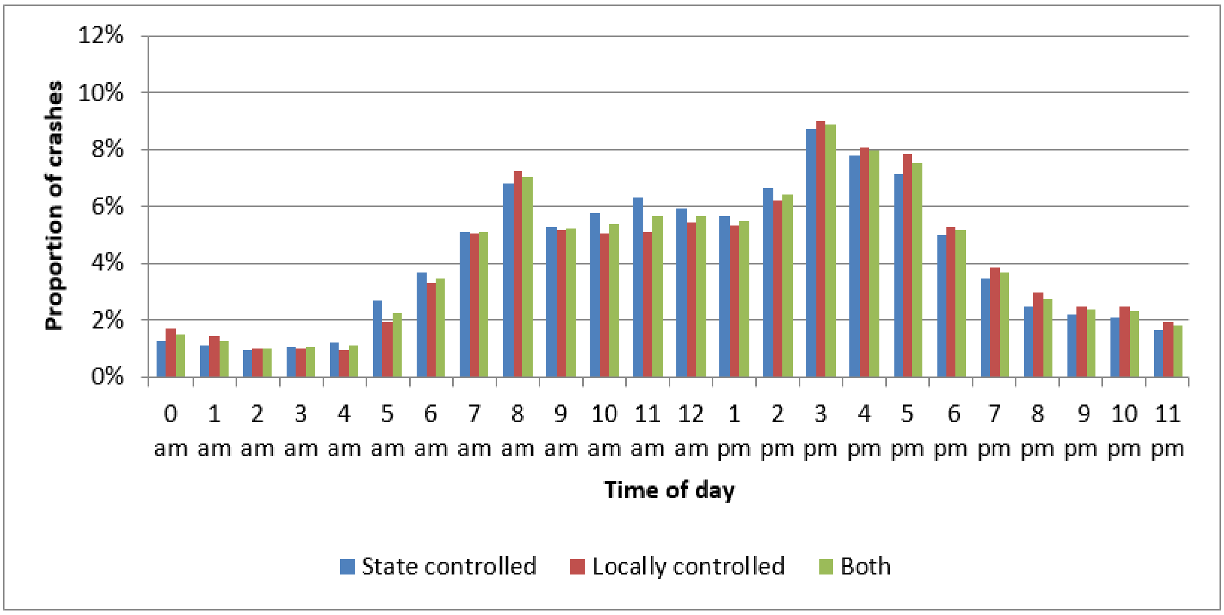


Figure 3.23: All injury crashes by time of day (2007-11)



3.3.9 Head-on Injury Crashes by Day of week

Figure 3.24 shows the weekly pattern of head-on injury crashes. On both state and locally controlled roads, Friday was the peak for head-on injury crashes. This peak is more observable on locally controlled roads with 19% of the crashes occurring on Fridays.

The peak period for all injury crashes was also Friday (Figure 3.25). However, the daily distribution for head-on crashes differs from that of all injury crashes. There are more head-on crashes on weekends (30%) compared to all injury crashes (25%).

Figure 3.24: Head-on injury crashes by day of week (2007-11)

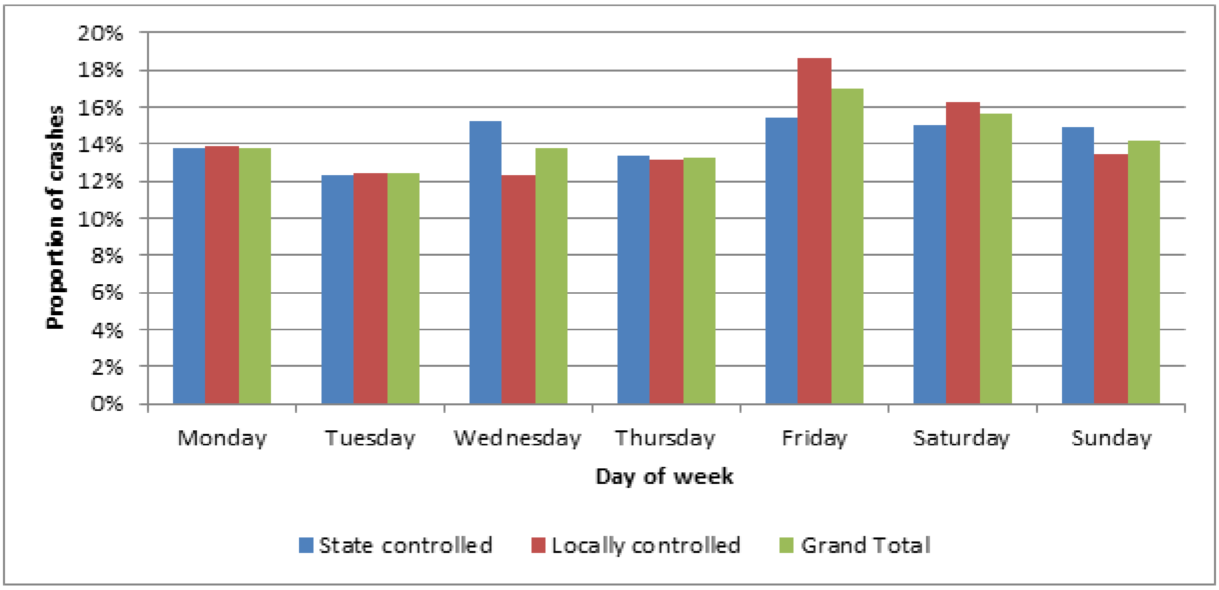
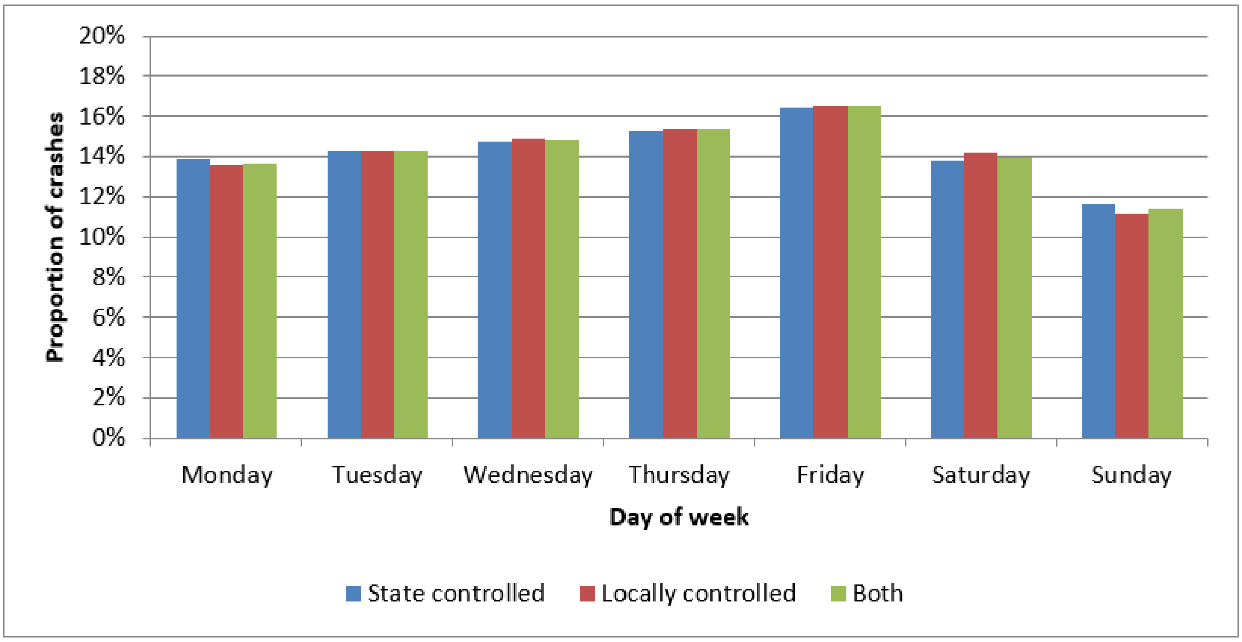


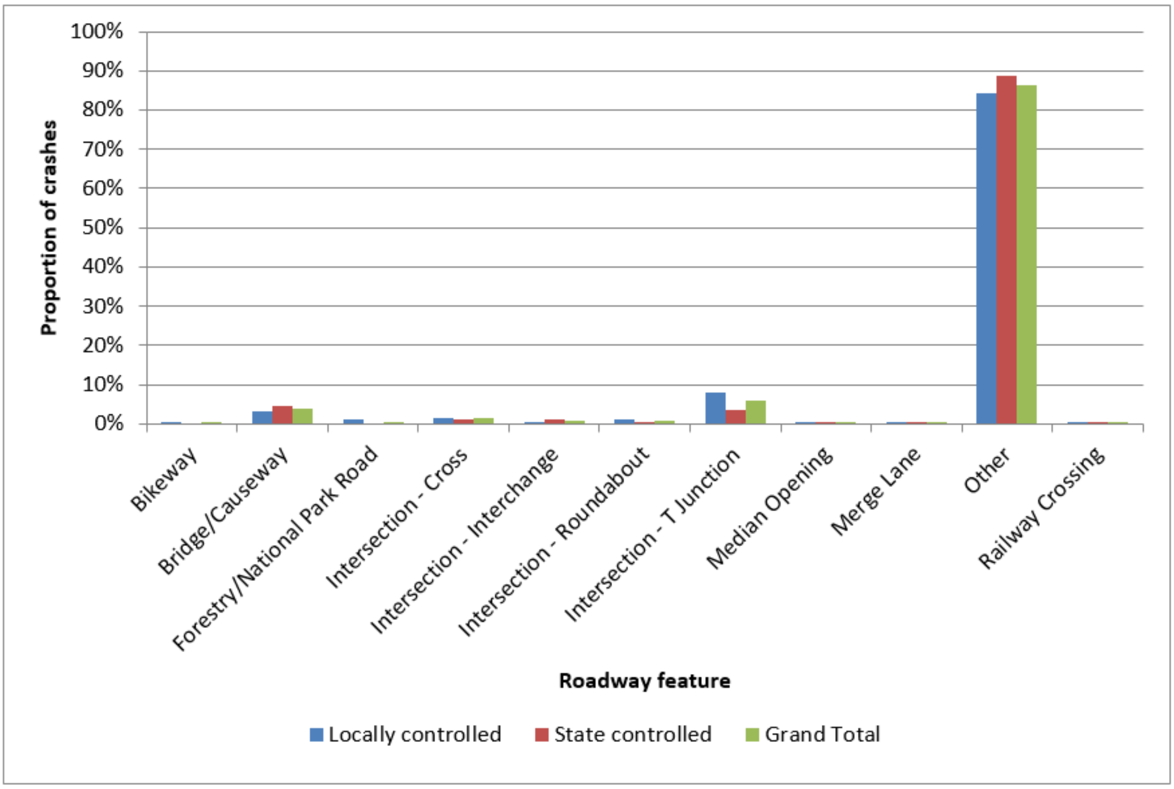
Figure 3.25: All injury crashes by day of week (2007-11)



3.3.10 *Head-on Injury Crashes by Roadway Features*

Figure 3.26 shows the proportion of head-on injury crashes by roadway feature. Most of the head-on crashes occurred at mid-block sections (86%), followed by 3-leg intersections (6%) and 4% on bridges/causeways. Most of the head-on crashes at intersections occurred at 3-leg unsignalised intersections (59% of the intersection head-on crashes).

Figure 3.26: Head-on injury crashes by roadway feature (2007-11)



3.3.11 Head-on Injury Crashes by Crash Factors

Figure 3.27 shows the breakdown of contributing crash factors in head-on injury crashes. Drivers disobeying the road rules is the most frequently recorded crash factor (80%), followed by young adult drivers between 16 and 24 years old (39%), senior adult drivers 60 years old or more (24%) and road condition (22%).

The contributions of these factors on head-on injury crashes are higher than for all injury crashes in Queensland during the same period (Figure 3.28):

- drivers disobeying the road rules – 80% for head-on injury crashes compared to 67% for all injury crashes
- young adult drivers between 16-24 years old – 39% for head-on injury crashes compared to 37% for all injury crashes
- senior adults 60+ years old – 24% for head-on injury crashes compared to 19% for all injury crashes
- road condition – 22% for head-on crashes compared to 10% for all injury crashes.

Figure 3.27: Head-on injury crashes by crash factor (2007-11)

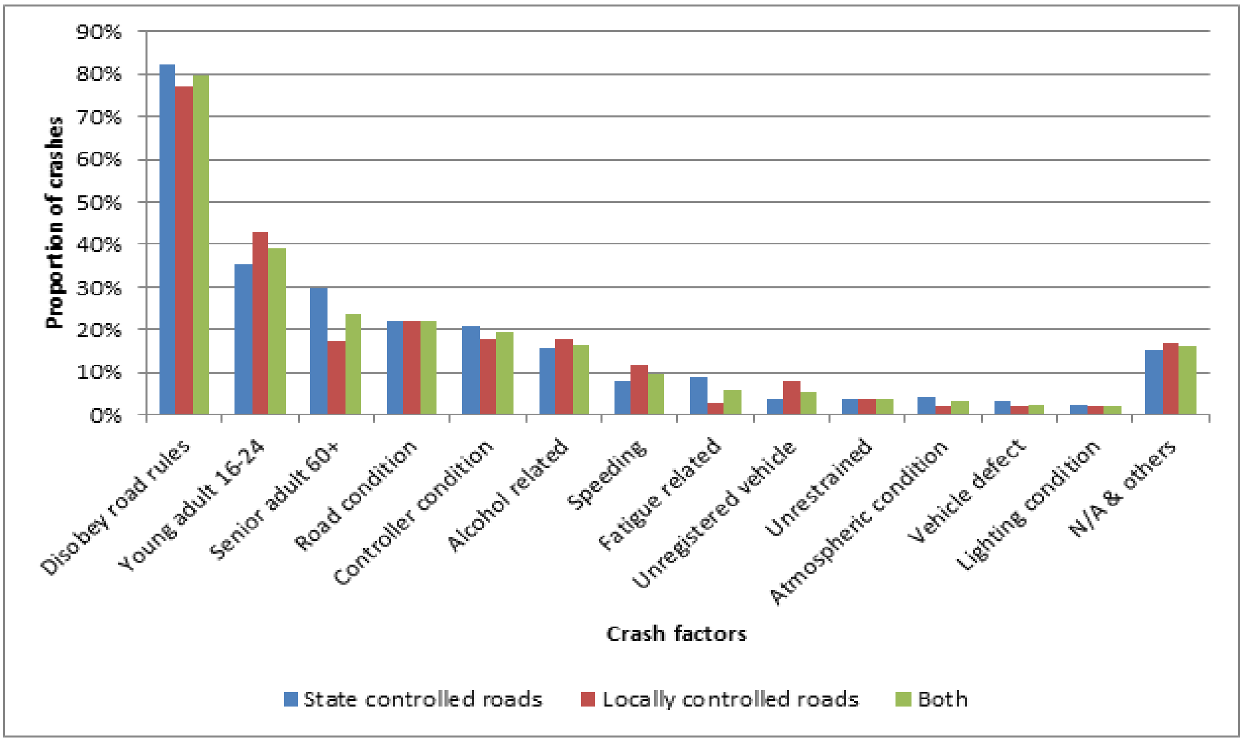
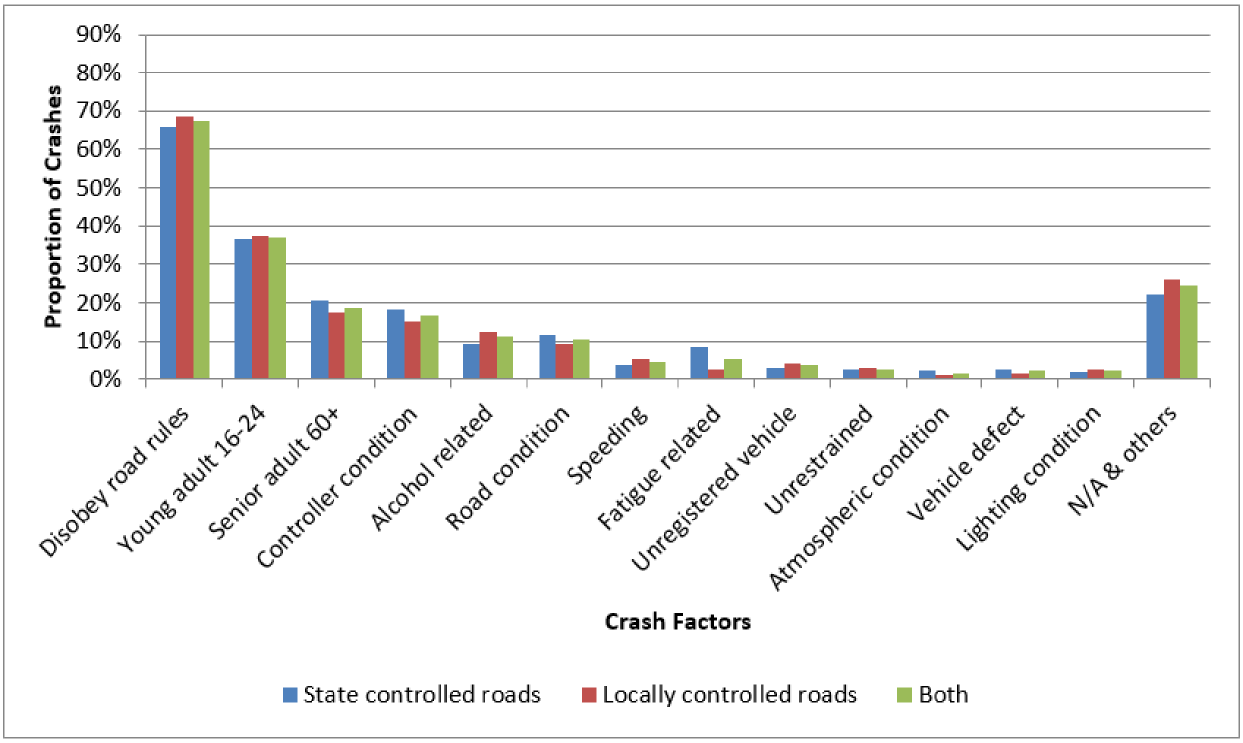


Figure 3.28: All injury crashes by crash factor (2007-11)



3.3.12 Head-on Injury Crashes by Primary Vehicle Controller Age

Figure 3.29 shows the age groups of the primary vehicle controller involved in head-on injury crashes. Young controllers aged 16-24 years old accounted for the highest proportion of head-on injury crashes (30%) followed by 30-39 years old (19%) and then the 40-49 years old (15%).

The proportion of young controllers 16-24 years old involved in head-on injury crashes (30%) is slightly higher than those involved in all injury crashes (29%) (Figure 3.30)

For the age groups less than 30 years, the risk of both head-on and all injury crashes on state-controlled roads were consistently lower than on locally controlled roads. For the age groups (30 years and above), the risk on state-controlled roads were consistently higher than on locally controlled roads.

Figure 3.29: Head-on injury crashes by age group of the primary vehicle controller (2007-11)

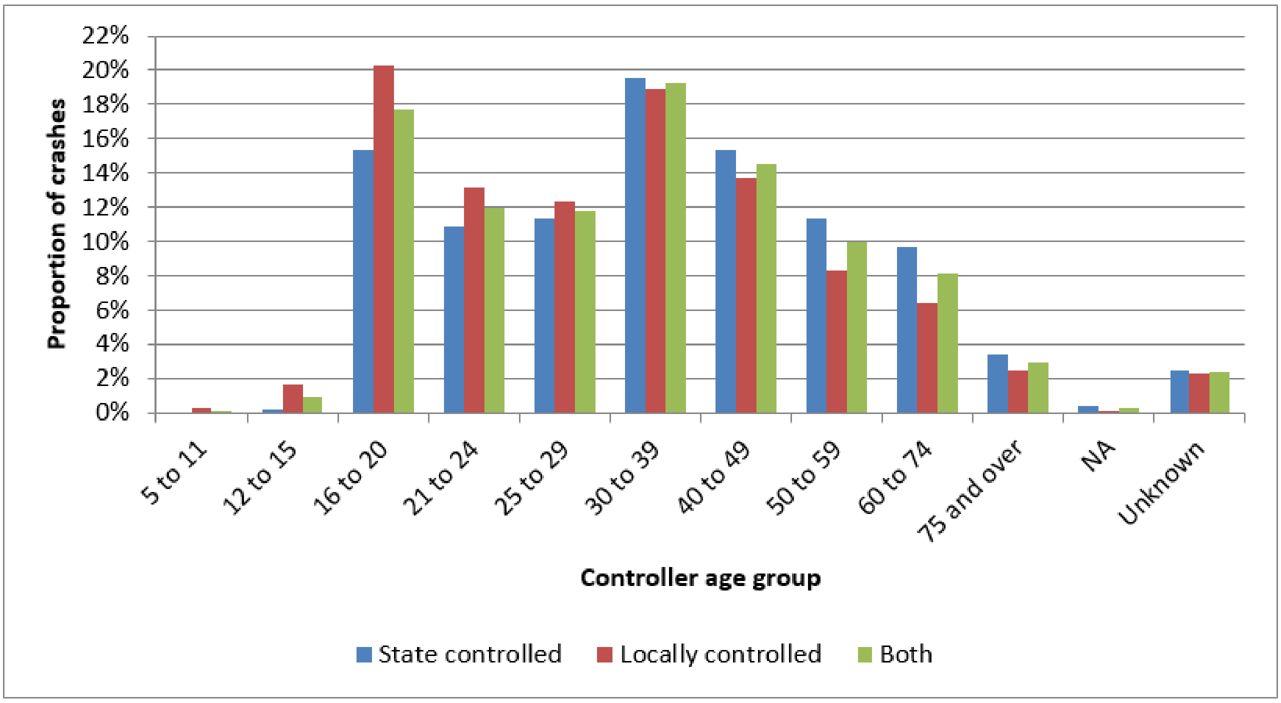


Figure 3.30: All injury crash by age group of the primary vehicle controller (2007-11)

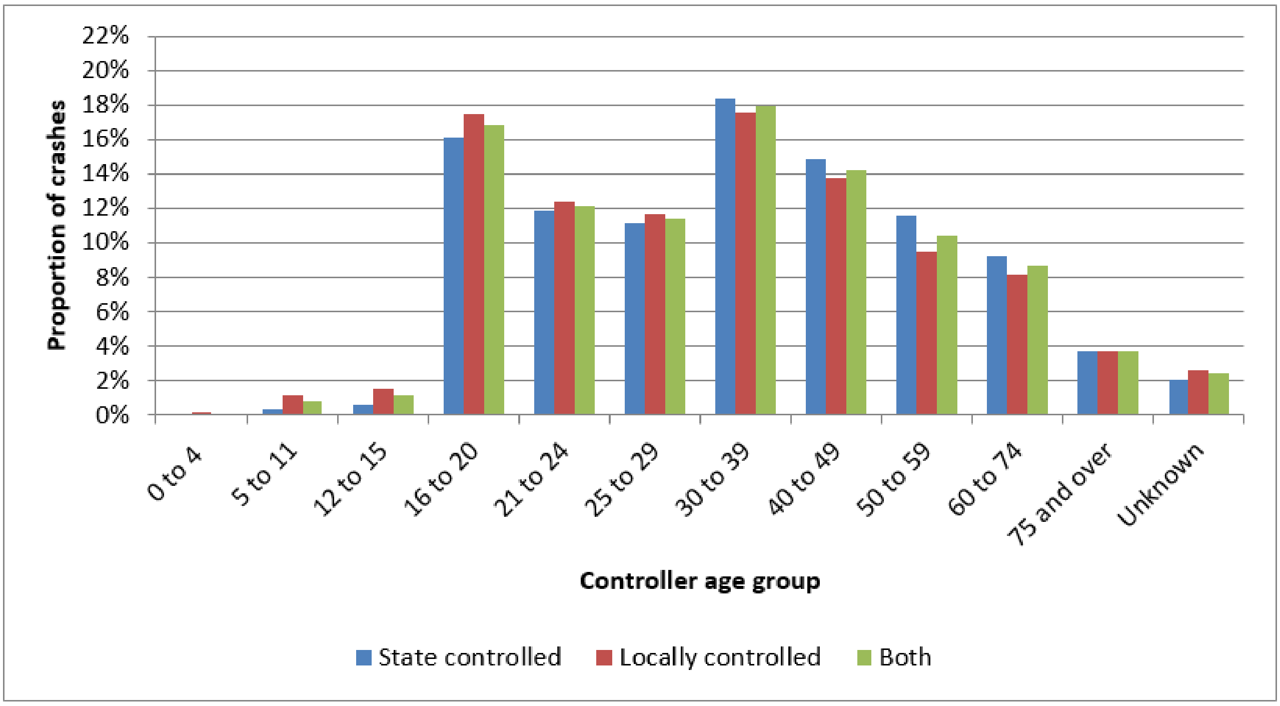
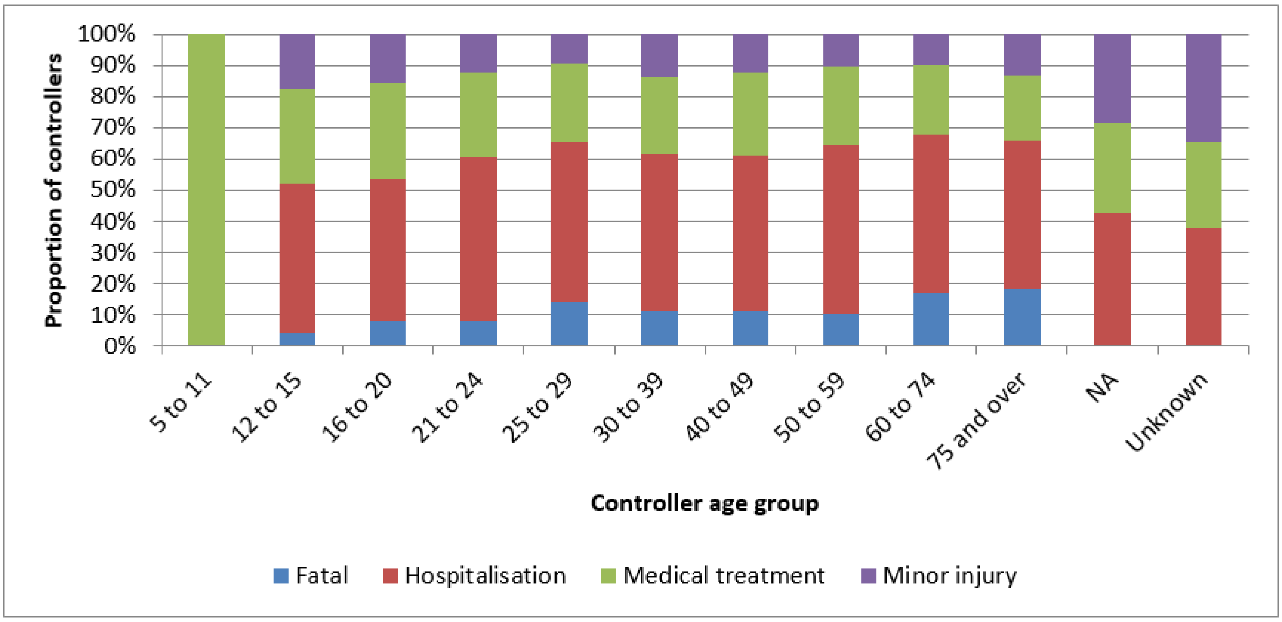


Figure 3.31 shows that the proportion of the head-on fatal crashes increased with the primary vehicle controller age (i.e. older drivers have higher fatality risk when involved in a head-on crash).

Figure 3.31: Head-on injury crashes by primary vehicle age and severity (2007-11)



3.3.13 *Head-on Injury Crashes by Primary Vehicle Controller Gender*

Figure 3.32 shows that male controllers of the primary vehicle accounted for about 75% of the head-on injury crashes, which is higher than the 65% for all injury crashes (Figure 3.33). Proportion of the female controllers is higher on state-controlled roads (27%) than on locally controlled roads (23%). In terms of male controllers the proportion on state-controlled roads was lower (73%) than on locally controlled roads (77%).

Figure 3.32: Head-on injury crashes by gender of the primary vehicle controller (2007-11)

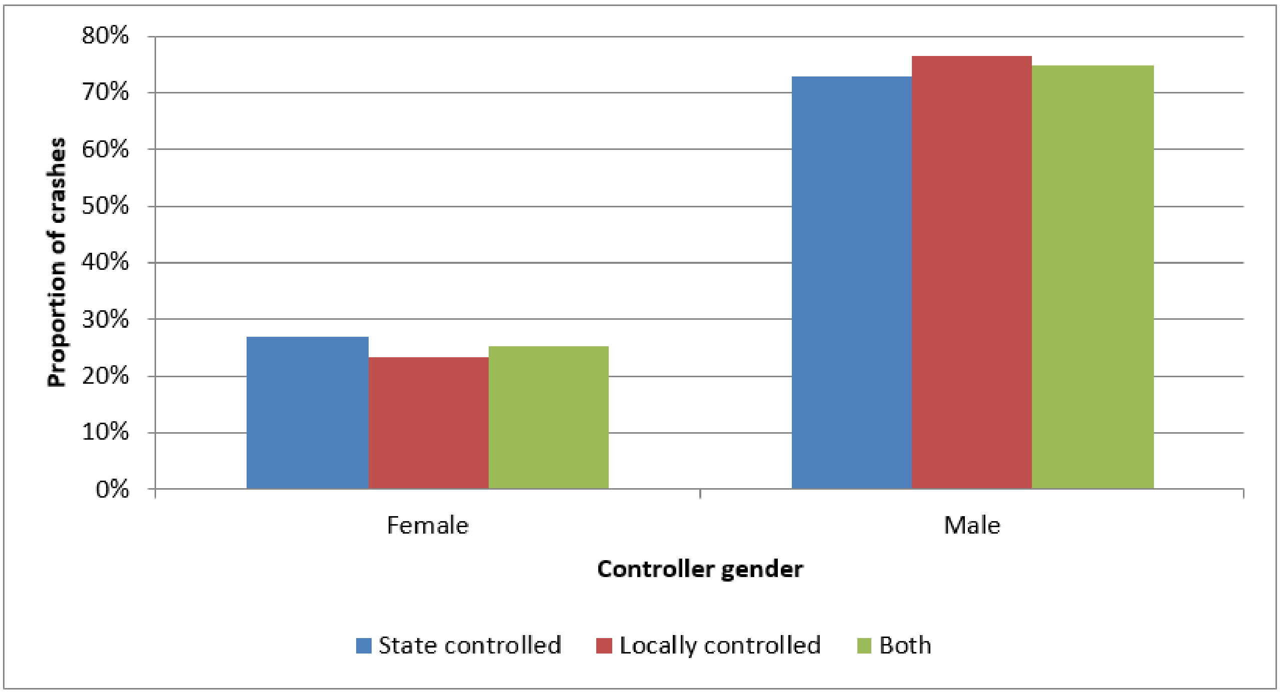


Figure 3.33: All injury crashes by gender of the primary vehicle controller (2007-11)

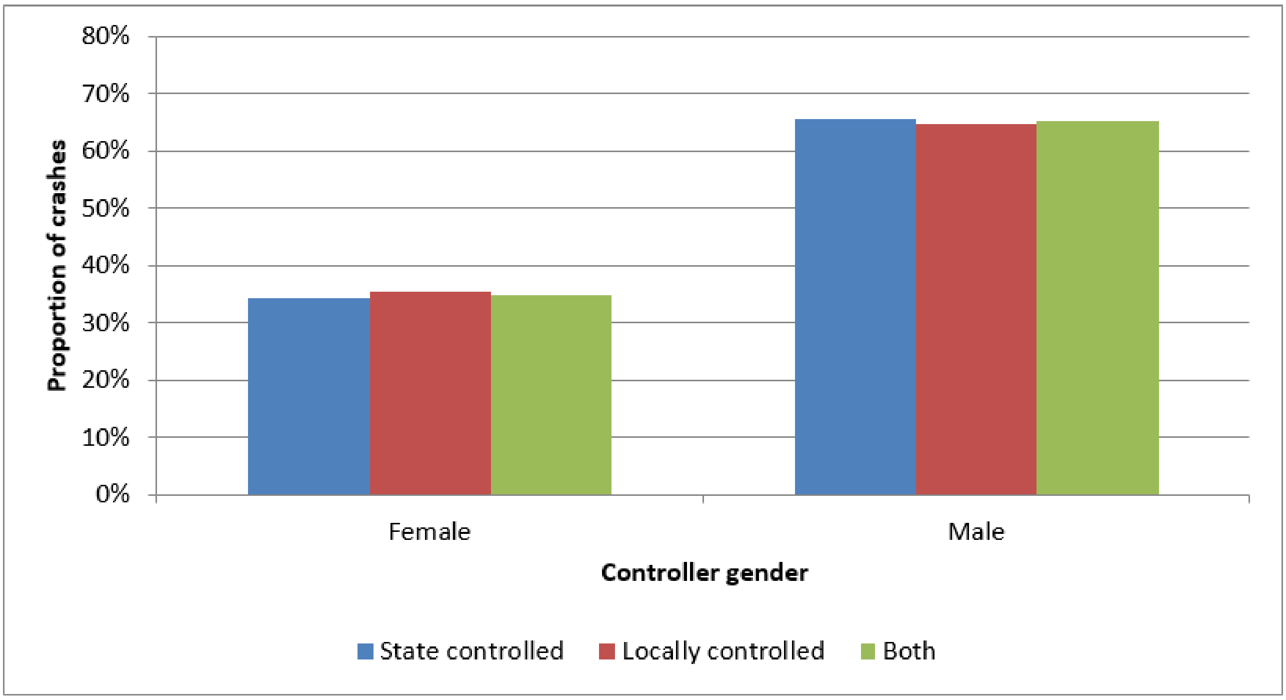
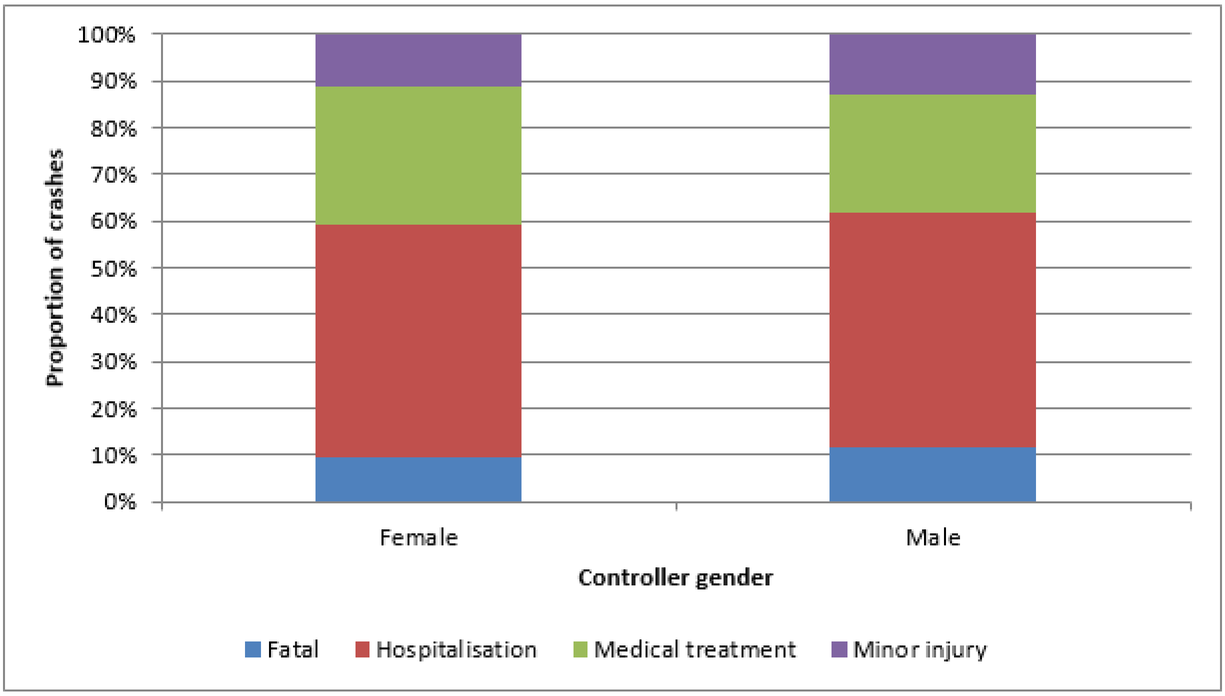


Figure 3.34 shows that the proportion of head-on fatal and FSI crashes were slightly higher for male controllers than female controllers.

Figure 3.34: Severity of head-on injury crashes by gender of the primary vehicle controller (2007-11)



3.3.14 Head-on Crashes by Primary Vehicle Age

Figure 3.35 illustrates the age of the primary vehicles involved in head-on injury crashes. The proportion of crashes showed no distinct pattern up to age 13, followed by gradual decline in crash numbers. This distribution is different for all injury crashes (Figure 3.36). For injury crashes, there is a steady decline in the proportion of injury crashes with age of primary vehicle.

The age of the primary vehicle does not have any distinct effect on the severity of head-on injury crashes once they have occurred (Figure 3.37).

Figure 3.35: Head-on injury crashes by primary vehicle age (2007-11)

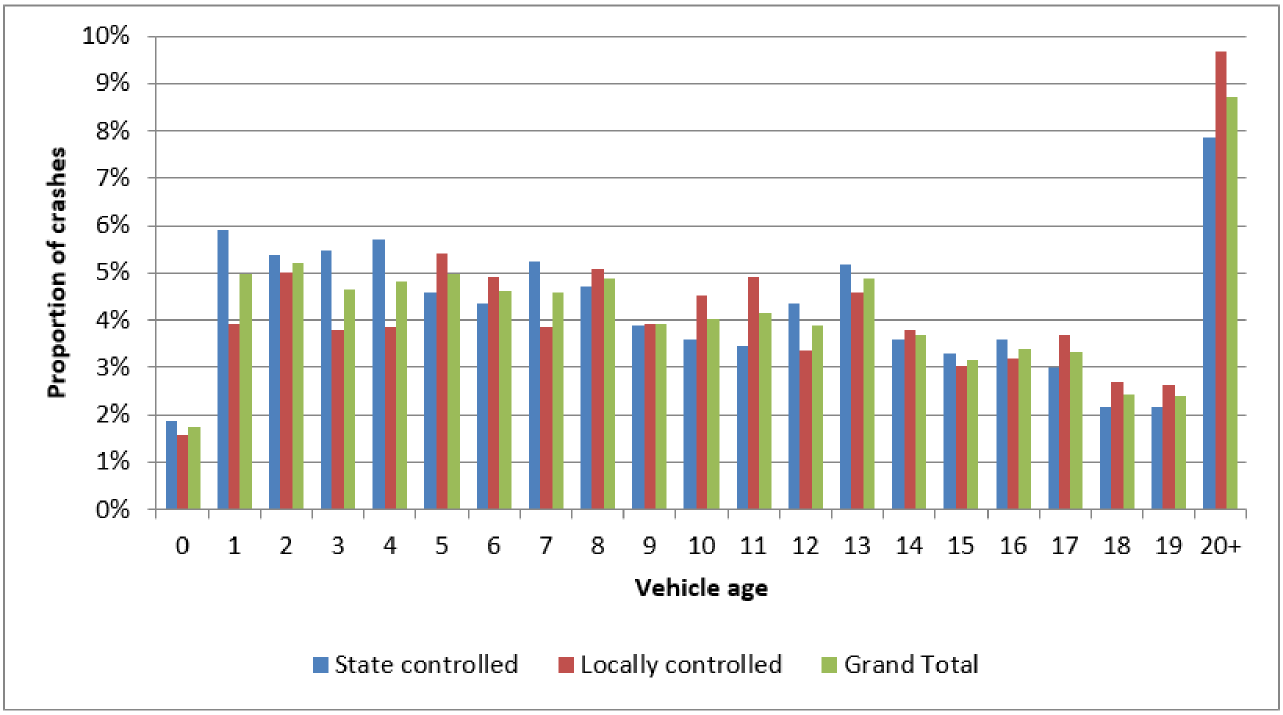


Figure 3.36: All injury crashes by primary vehicle age (2007-11)

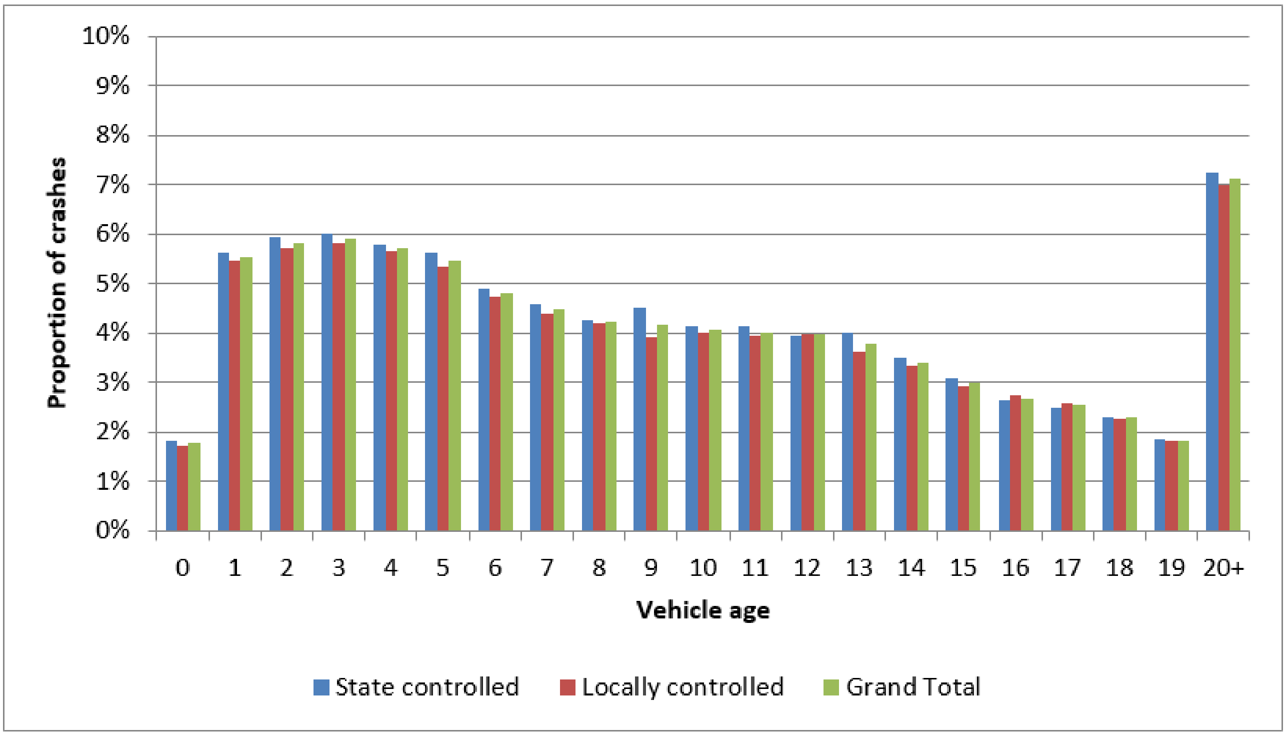
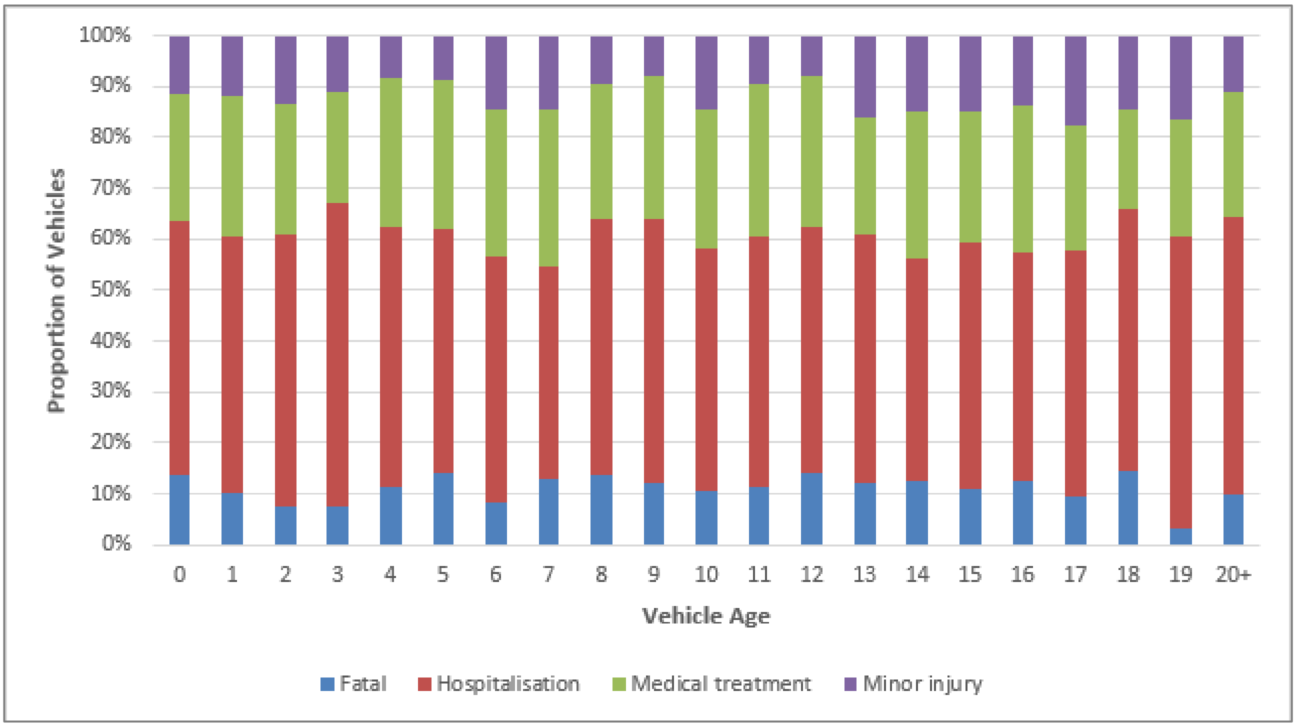


Figure 3.37: Head-on injury crashes by primary vehicle age and severity (2007-11)



3.3.15 Head-on Crashes by Primary Vehicle Type

Figure 3.38 to Figure 3.40 show the different vehicle units by primary vehicle involved in head-on and all injury crashes. Notable findings include:

- light passenger vehicles were involved in 83% (Figure 3.38) of head-on injury crashes compared to 80% for all injury crashes (Figure 3.39)
- motorcycles/mopeds were involved in 9% (Figure 3.38) of head-on injury crashes compared to 7% for all injury crashes (Figure 3.39)
- motorcycles/mopeds had the highest FSI proportion of head-on injury crashes – 75% of motorcycle head-on crashes resulted in FSI crash (Figure 3.40)
- heavy freight vehicles were involved in 5% of head-on and all injury crashes
- head-on crashes involving heavy vehicles were more severe in terms of fatalities - 21% of head-on crashes were fatal, and a further 39% resulted in a hospitalisation (Figure 3.40)
- proportion of head-on crashes involving heavy vehicles is higher on state-controlled roads than on locally controlled roads, while the proportion of motorcycles head-on crashes is lower on state-controlled roads.

Figure 3.38: Head-on injury crashes by primary vehicle type (2007-11)

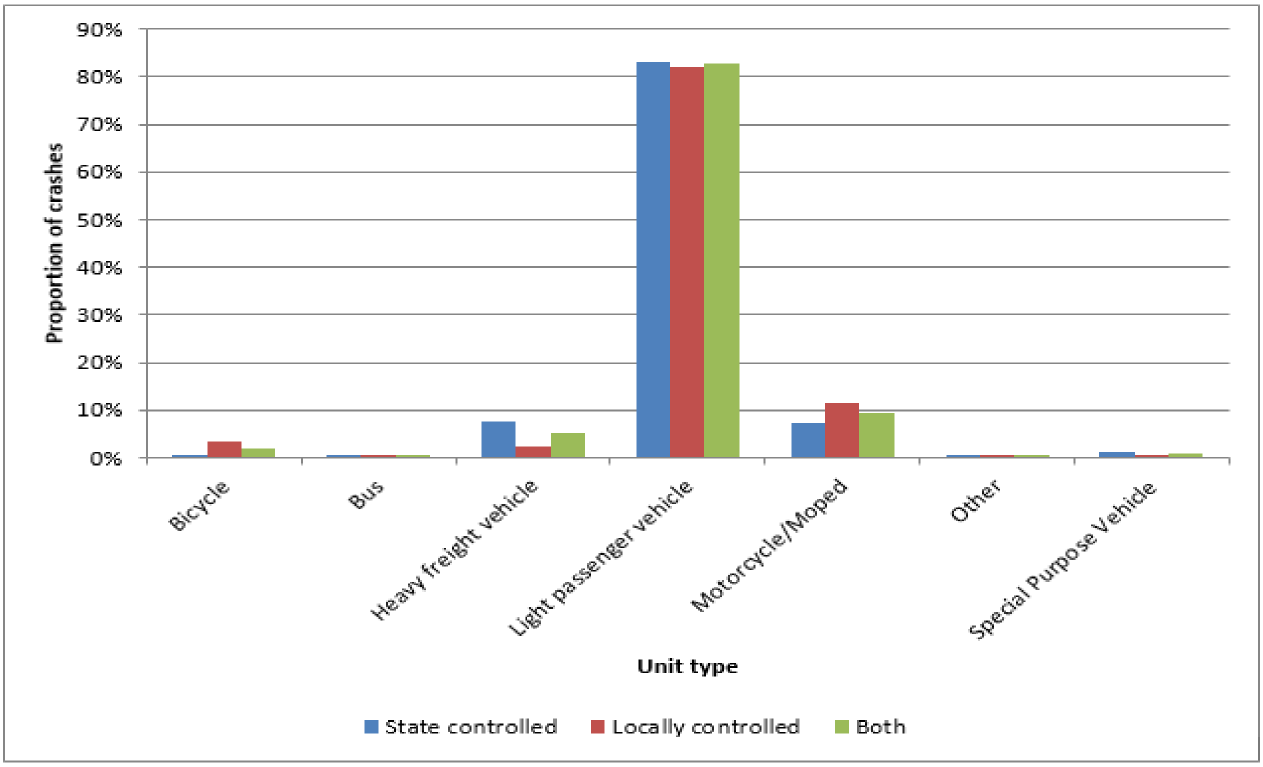


Figure 3.39: All injury crashes by primary vehicle type (2007-11)

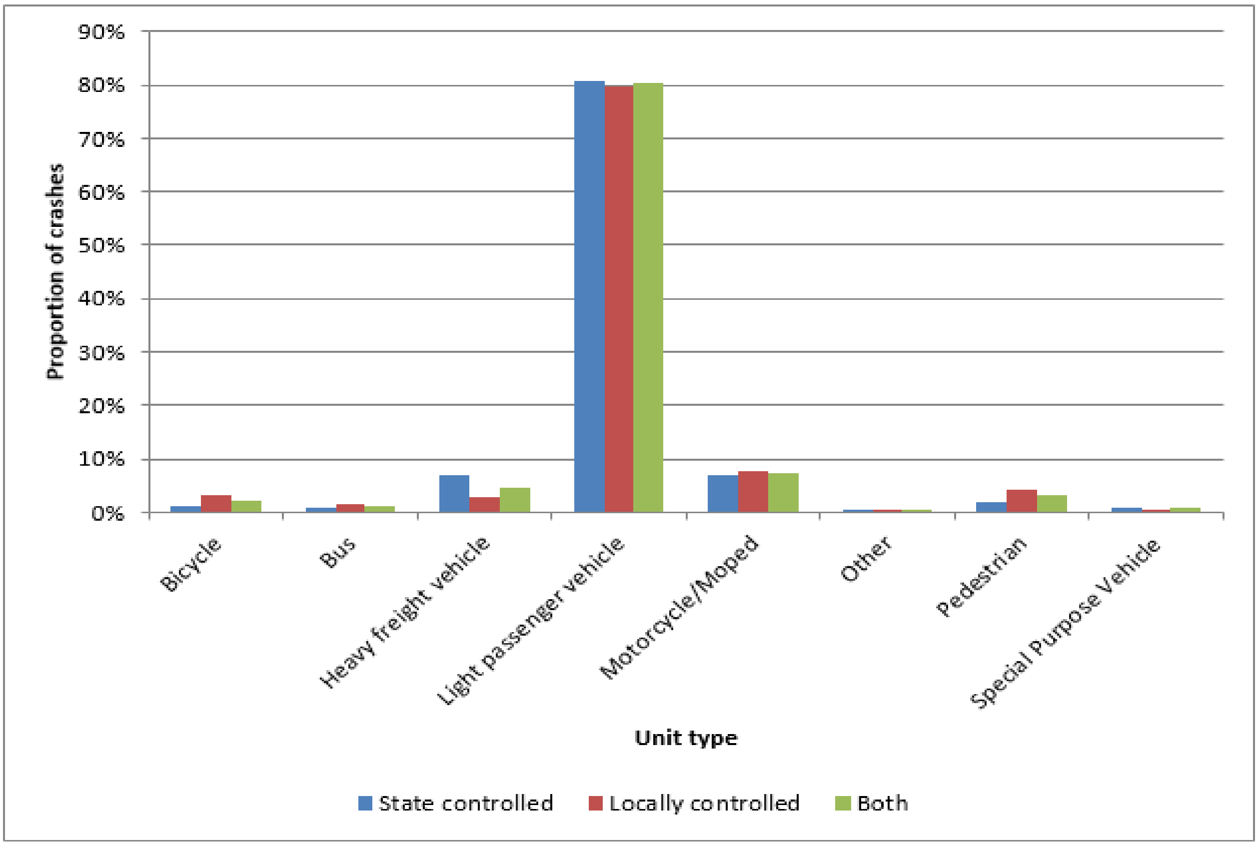
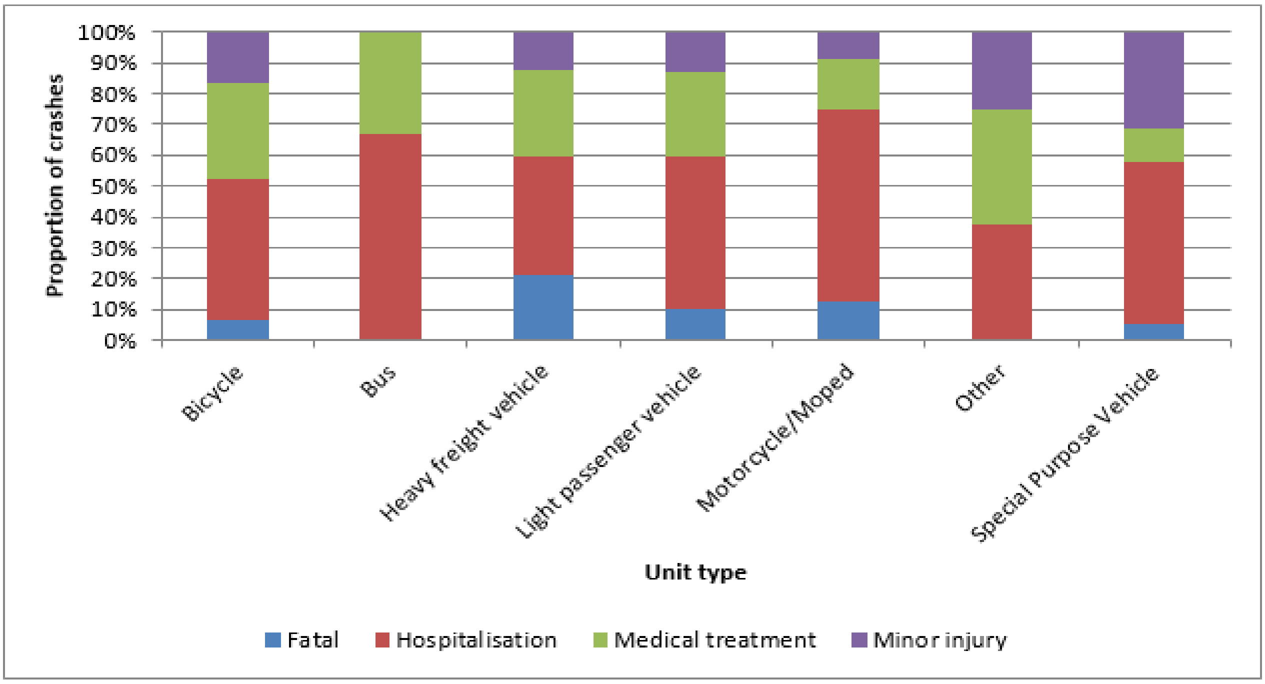


Figure 3.40: Head-on injury crashes by primary vehicle type and severity (2007-11)



3.3.16 Head-on High Crash Risk Sections – State-controlled Roads

High risk head-on crashes on the state-controlled roads have been provided based on total crash numbers, crash rate per kilometre (i.e. collective risk) and crash rate per vehicle kilometre travelled (VKT) (i.e. individual risk). Total crash number and crash rate per kilometre tend to select sites with high traffic volume, whilst the crash rate per VKT favours sites with low traffic volume.

The methods can be used in isolation or in combination to overcome the various disadvantages depending on the objective of the study. To account for crash severity, the parameters are expressed in crash cost. Generally the recommended method for selecting sites for treatment is by using crash cost by crash type (Austroads 2009, Andreassen 1992). However, as reported in Austroads (2009) whichever method is used to identify hazardous locations there needs to be sufficient flexibility to ensure that:

- sites which have recently become a problem for obvious reasons do not have to experience another two or four years of crashes before they are considered
- sites with few crashes, but requiring low cost treatments are not excluded.

TMR derived 2013 willingness to pay (WTP) crash cost values are used (Table 3.3).

Table 3.3: Willingness to pay crash cost – 2013 dollar value

Crash severity	Crash cost -2013 value
Fatal	8,147,446
Hospitalisation	365,761
Medical treatment	106,907
Minor injury	37,944

The top 10 high risk road sections for each method are provided in the following sections. The complete list for all roads are provided as an attachment in an Excel spreadsheet.

State roads with high number of head-on crashes

Figure 3.41 shows the top 10 road sections with the highest number of head-on injury crashes. These road sections included 32A (Kennedy Highway between Cairns and Mareeba - recorded the highest number of head-on injury crashes), seven Bruce Highway sections, 17B (Cunningham Highway between Ipswich and Warwick) and 20A (Captain Cook Highway between Cairns and Mossman).

Table 3.4 shows the top 10 road sections with the highest head-on injury crashes based on crash cost. The top 50 high risk head-on crash road sections are provided in Appendix A, Table A 1 .

Figure 3.41: Top 10 road sections with highest numbers of head-on injury crashes by severity (2007-11)

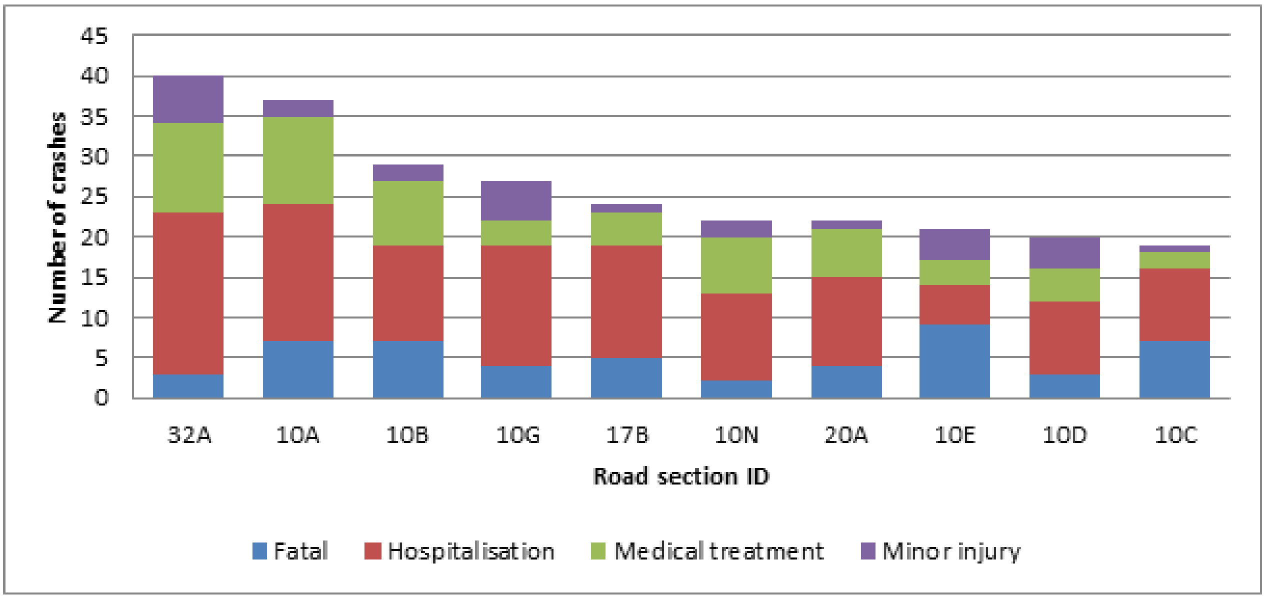


Table 3.4: Top 10 road sections with the highest number of head-on injury crashes (2007-11)

Road Sections	Fatal	Hospitalisation	Medical treatment	Minor injury	Total	Annual average crash cost
10E	9	5	3	4	21	$15,125,663
18B	8	6	3	1	18	$13,546,560
10A	7	17	11	2	37	$12,900,385
10B	7	12	8	2	29	$12,470,480
10C	7	9	2	1	19	$12,115,146
10L	6	3	1	0	10	$10,017,773
17B	5	14	4	1	24	$9,264,691
40A	5	10	2	0	17	$8,921,731
10H	5	10	1	1	17	$8,907,938
10G	4	15	3	5	27	$7,717,328

Head-on collective risk for state-controlled roads

The collective risk shows the total number of injury crashes over a given length of road. The collective risk is calculated by dividing the number of injury crashes per annum by the length of road section (i.e. crashes per km). The top 10 state-controlled road sections with high collective risk for head-on injury crashes based on crash cost are shown in Table 3.5. The top 50 high collective head-on crash risk road sections are provided in Appendix A, Table A 2 .

Table 3.5: Top 10 state-controlled roads with the highest head-on crash cost per km (collective risk), 2007-11

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total HO injury crashes	Total HO FSI crashes	Annual average HO injury crashes per km	Annual average injury crash cost per km	Annual average HO injury crashes per 100M veh-km	Annual average injury crash cost per 1000 veh-km
9901	1.78	7708	1	1	0.112	$915,443	3.99	$326.00
904	6.63	16330	4	4	0.121	$748,359	2.02	$126.00
U27	6.45	NA	3	3	0.093	$516,609	NA	NA
142	9.97	9833	4	4	0.08	$497,655	2.24	$138.00
208	4.66	15107	4	3	0.172	$385,660	3.11	$70.00
914	10.56	NA	4	4	0.076	$322,470	NA	NA
U95	7.1	15842	5	4	0.141	$263,426	2.44	$46.00
150B	25.72	19389	14	11	0.109	$214,776	1.54	$30.00
110	9.56	19045	4	3	0.084	$186,546	1.20	$26.00
40A	50.53	6309	17	15	0.067	$176,563	2.92	$76.00

Head-on individual risk for state-controlled roads

The individual risk show the casualty crash rates per vehicle kilometre travelled (VKT) – and so effectively represent the risk faced by an individual driver. The individual risk is calculated by dividing the frequency of crashes per annum by the distance travelled on each road section per annum (crashes per VKT or crash cost per VKT).

The top 10 high state-controlled road collective risk sections for head-on crashes based on crash cost are shown in Table 3.6 . The top 50 high collective head-on crash risk road sections are provided in Appendix A, Table A 3 .

Table 3.6: Top 10 state-controlled roads with high head-on crash cost per VKT (individual risk), 2007-11

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total HO injury crashes	Total HO FSI crashes	Annual average HO injury crashes per km	Annual average HO injury crash cost per km	Annual average HO injury crashes per 100M veh-km	Annual average HO injury crash cost per 1000 veh-km
4808	17.77	208	1	1	0.011	$91,699	14.82	$1,208.00
6404	10.72	579	2	1	0.037	$153,956	17.66	$728.00
1751	4.3	2580	1	1	0.047	$379,392	4.94	$402.00
476	58.98	215	1	1	0.003	$27,626	4.32	$352.00
9901	1.78	7708	1	1	0.112	$915,443	3.99	$326.00
665	15.1	933	1	1	0.013	$107,913	3.89	$316.00
1204	13.86	2137	3	2	0.043	$235,683	5.55	$302.00
462	24.15	34	1	1	0.008	$3,030	66.75	$244.00
94B	163.73	119	2	2	0.002	$10,399	5.63	$240.00
2020	18.44	1502	6	5	0.065	$105,395	11.87	$192.00

3.4 Run-off-road Crashes

Run-off-road (ROR) crashes included in the analysis have been selected on the basis of DCA codes that indicate a vehicle leaving the carriageway and often into a roadside object. The DCA codes considered for run-off-road crashes are presented in Table 3.7.

In all, run-off-road crashes accounted for 21% of the 69 533 injury crashes and 27% of FSI crashes during the five year period. About 48% of the ROR injury crashes occurred on state-controlled roads.

On state-controlled roads, run-off-road crashes accounted for 23% of injury crashes and 29% of FSI crashes.

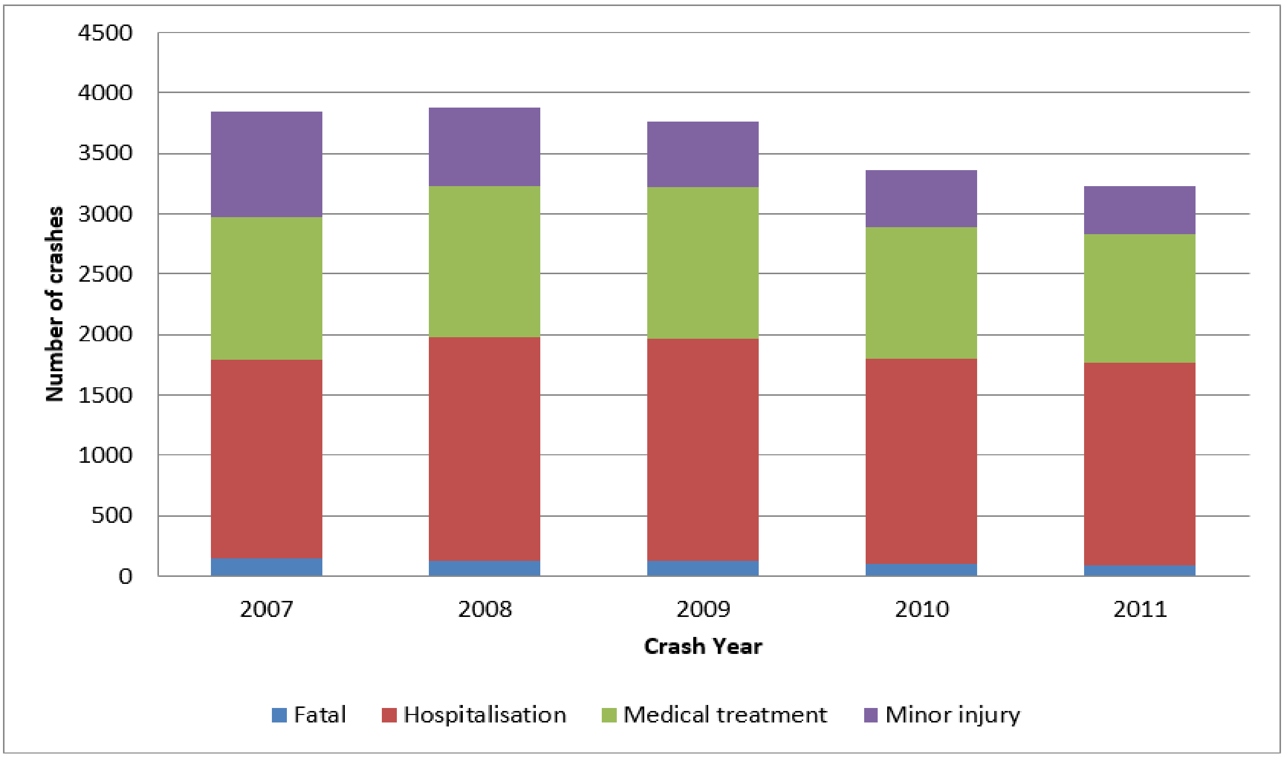
Table 3.7: Run-off-road crashes by DCA code

DCA Code	Description	Action
700	Off path on straight – Other	Include as Run-off-road
701	Off path on straight – Off carriageway to left	Include as Run-off-road
702	Off path on straight – Off Carriageway to right	Include as Run-off-road
703	Off path on straight – Left off carriageway into object	Include as Run-off-road
704	Off path on straight – Right off carriageway into object	Include as Run-off-road
705	Off path on straight – Out of control on carriageway	Analysed separately in Section 5
706	Off path on straight – Left turn	Include as Run-off-road
707	Off path on straight – Right turn	Include as Run-off-road
708	Off path on straight – Mounts traffic island	Include as Run-off-road
800	Off path on curve – Other	Include as Run-off-road
801	Off path on curve – Off carriageway right bend	Include as Run-off-road
802	Off path on curve – Off carriageway left bend	Include as Run-off-road
803	Off path on curve – Off right bend into object	Include as Run-off-road
804	Off path on curve – Off left bend into object	Include as Run-off-road
805	Off path on curve – Out of Control on Carriageway	Analysed separately in Section 5
806	Off path on curve – Left turn	Include as Run-off-road
807	Off path on curve – Right turn	Include as Run-off-road
808	Off path on curve – Mounts traffic island	Include as Run-off-road
502	Overtaking – Out of control	Include as Run-off-road

3.4.1 Annual Distribution of Run-off-road Crashes

Figure 3.42 shows the annual ROR injury crashes from 2007 to 2011. Both total injury and FSI ROR crashes peaked in 2008 and have declined since then. There has been 45% reduction in fatal ROR crashes; 15% reduction in FSI crashes and 16% in all ROR injury crashes from 2007 to 2011.

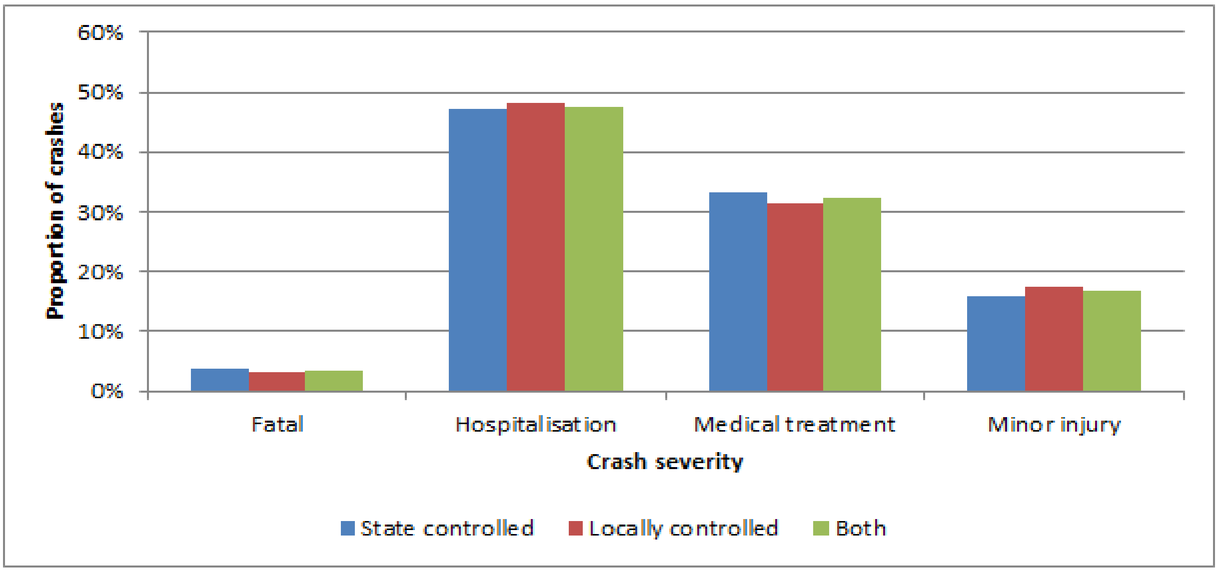
Figure 3.42: Run-off-road injury crashes by year and severity (2007-11)



3.4.2 *Run-off-road Crash Severity*

Figure 3.43 shows the severity of ROR injury crashes by road authority. About 4% of the ROR injury crashes on state-controlled roads were fatal crashes compared to 3% on locally controlled roads. Compared to all injury crashes, ROR injury crashes were more severe in terms of the proportion of fatal and FSI crashes. About 51% of ROR injury crashes were FSI crashes compared to the 40% for all injury crash types.

Figure 3.43: Run-off-road injury crashes by road authorities and severity (2007-11)

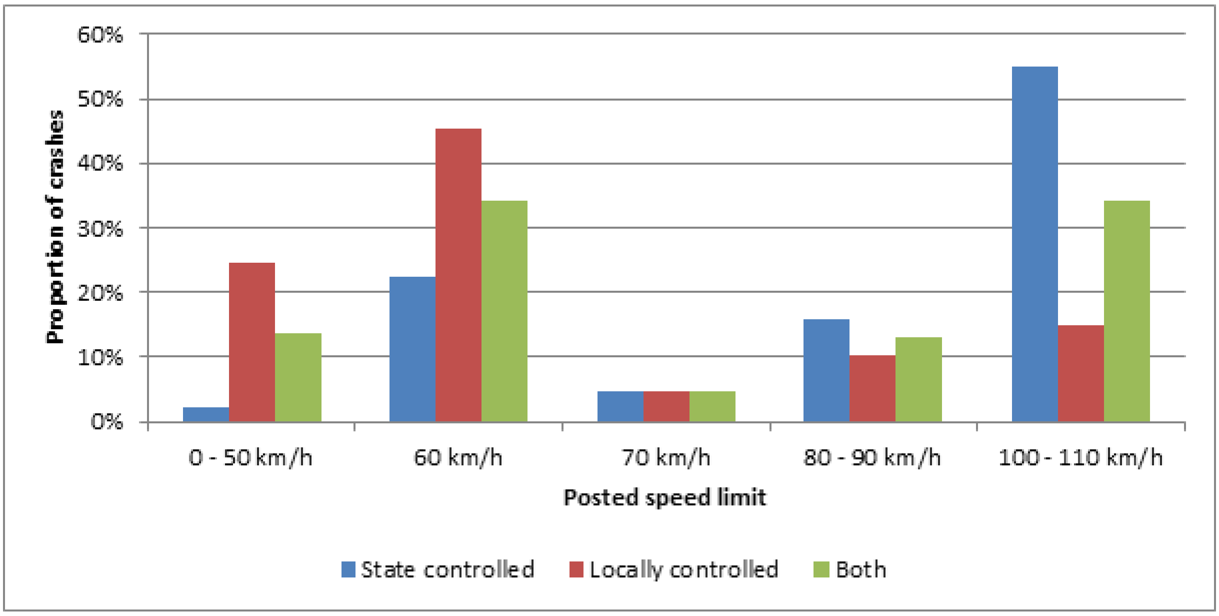


3.4.3 Run-off-road Injury Crashes by Posted Speed Limit

Figure 3.44 show the breakdown of ROR injury crashes by speed zone by road authority. Majority of ROR injury crashes on locally controlled roads occurred in 0- 60 km/h posted speed limit zones, while on state-controlled roads, most occurred in 100-110 km/h posted speed limit zones.

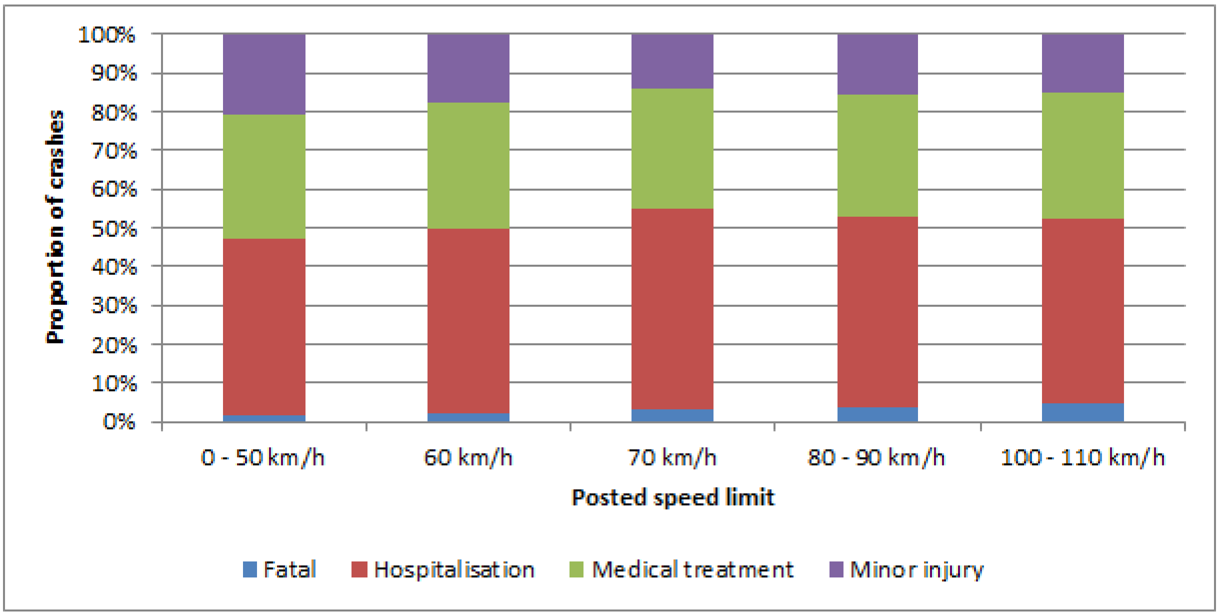
Compared to all injury crashes, the proportion of ROR injury crashes (47%) on high speed roads (80 km/h or more) is higher compared to all injury crashes (27%).

Figure 3.44: Run-off-road injury crashes by posted speed limit (2007-11)



Crash severity for ROR crashes generally increased with increasing vehicle speed. Figure 3.45 shows that the proportion of fatal ROR crashes increased with posted speed limits. The proportion of the ROR injury crashes that resulted in FSI increased with increasing speed limit before peaking at 70 km/h speed limit.

Figure 3.45: Run-off-road injury crashes by posted speed limit and severity (2007-11)



3.4.4 *Run-off-road Injury Crashes by Horizontal Alignment*

Figure 3.46 shows that 44% of ROR injury crashes occurred on curves. This is high considering that the road network contains more straight sections. This proportion is also higher than the 23% recorded for all injury crashes that occurred on curves (Figure 3.11).

The proportion of ROR crashes that resulted in a FSI is slightly higher on curved road sections than on the straight sections (Figure 3.47).

Figure 3.46: Run-off-road injury crashes by horizontal alignment (2007-11)

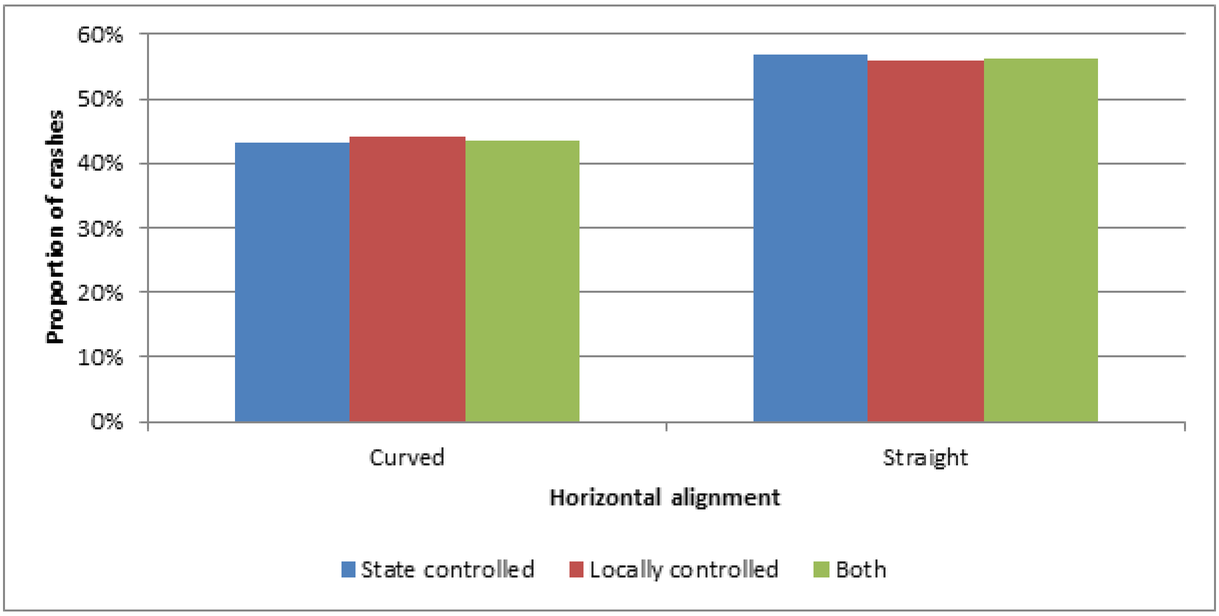
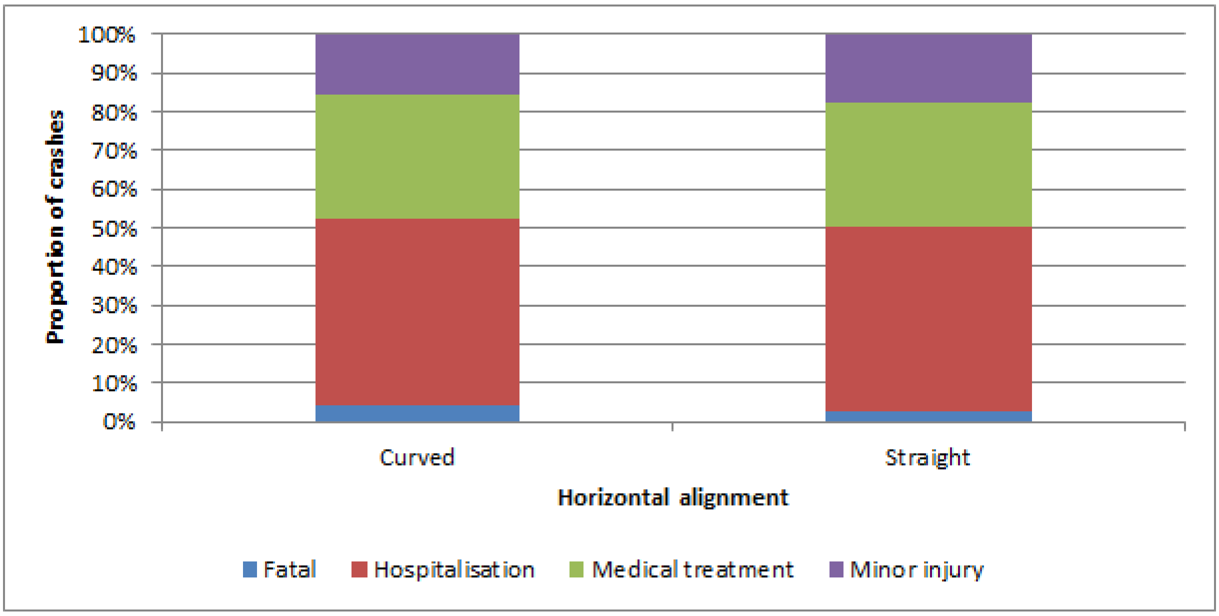


Figure 3.47: Run-off-road injury crashes by horizontal alignment and severity (2007-11)



3.4.5 *Run-off-road Injury Crashes by Vertical Alignment*

Figure 3.48 shows that about 31% of ROR injury crashes occurred on a grade, dip or crest. This is higher than the 25% for all injury crashes (Figure 3.14). Crests and dips accounted for about 10% of ROR injury crashes on state-controlled roads and slightly higher at 12% on locally controlled roads.

Figure 3.49 shows that the proportion of FSI crashes was generally consistent across the different vertical alignments. FSI proportion was highest, but marginally on dips followed by crests.

Figure 3.48: Run-off-road injury crashes by vertical alignment (2007-11)

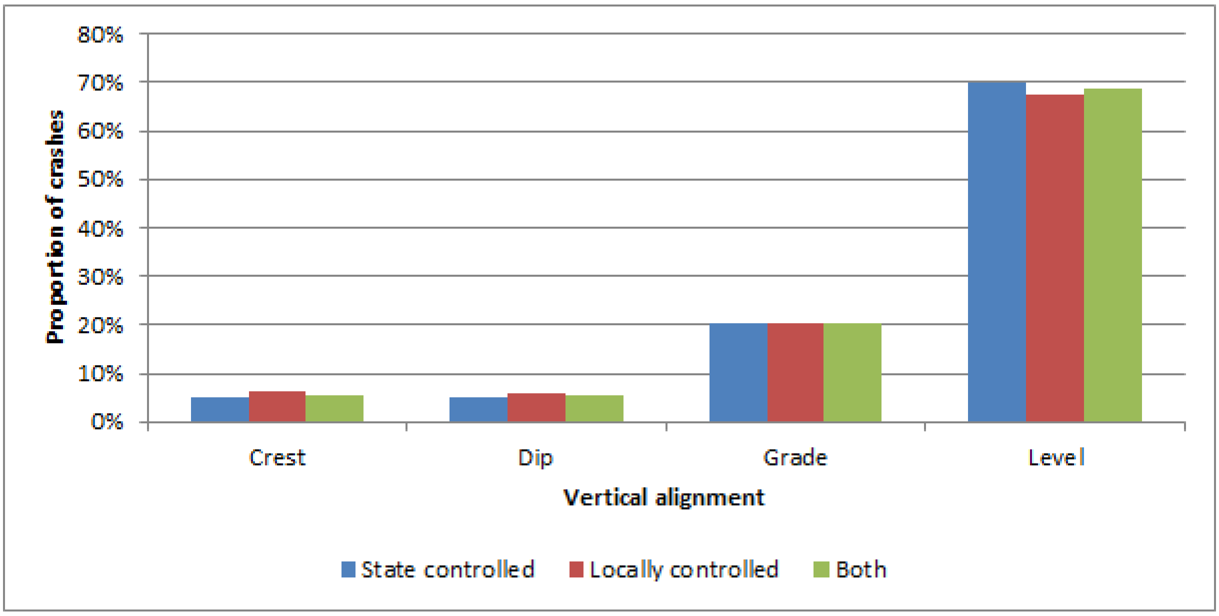
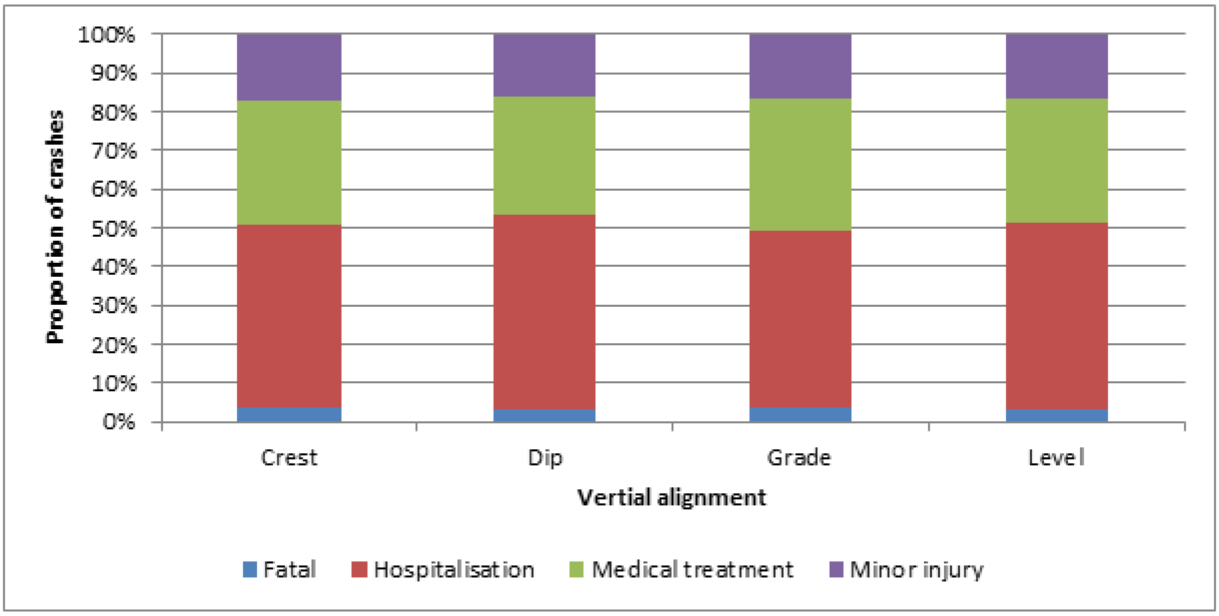


Figure 3.49: Run-off-road injury crashes by vertical alignment and severity (2007-11)



3.4.6 Run-off-road Injury Crashes by Road Surface Condition

Figure 3.50 shows that 22% of ROR injury crashes occurred on wet road surfaces. This is higher than the 16% recorded for all injury crashes.

Unsealed sections accounted for about 10% of the ROR injury crashes on locally controlled roads and about 2% of those on state-controlled roads. Combined 6% of ROR injury crashes occurred on unsealed roads, two times more than the proportion of all injury crashes on unsealed roads (3%).

Figure 3.50: Run-off-road injury crashes by road surface condition (2007-11)

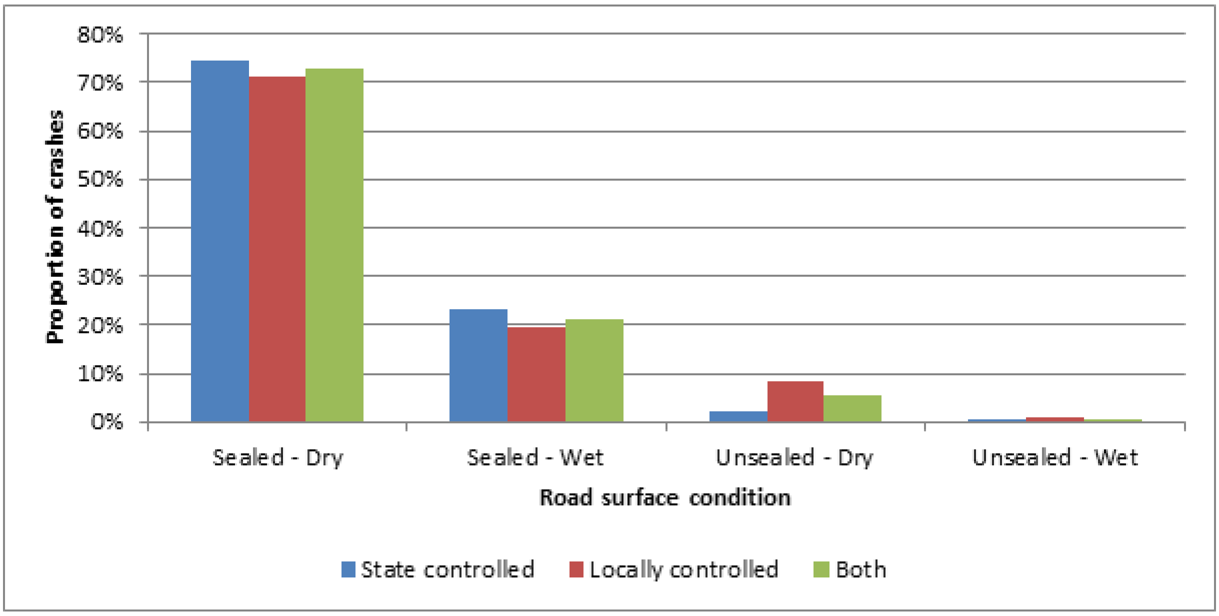
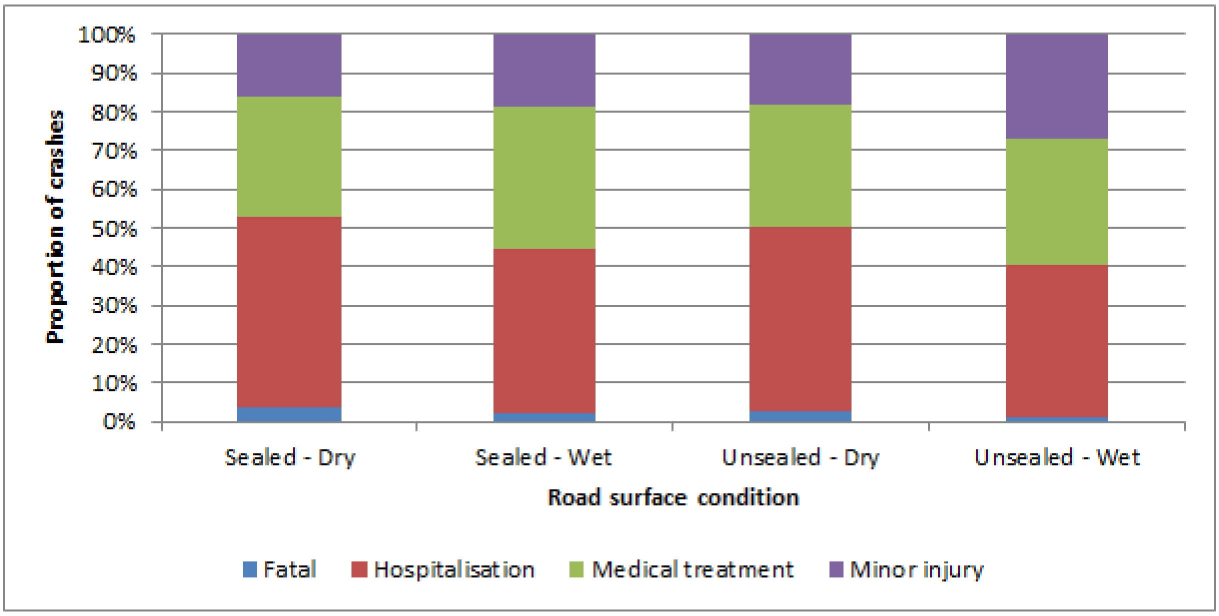


Figure 3.51 shows that the proportion of ROR crashes that resulted in an FSI crash is higher on dry road surfaces compared to those of wet road surface condition. Similarly, the risk of a ROR

crash that resulted in an FSI crash is higher on sealed roads compared to those on unsealed roads.

Figure 3.51: Run-off-road injury crashes by road surface condition and severity (2007-11)



3.4.7 Run-off-road Injury Crashes by Lighting Condition

Figure 3.52 shows the proportion of injury crashes by lighting conditions. About 46% of ROR injury crashes occurred during adverse lighting conditions (i.e. dark/dusk/dawn). This proportion is higher than the 30% for all injury crashes (Figure 3.20). Half of ROR injury crashes on locally controlled roads occurred during dark/dusk/dawn periods, higher than on state-controlled roads.

Figure 3.52: Run-off-road injury crashes by lighting condition (2007-11)

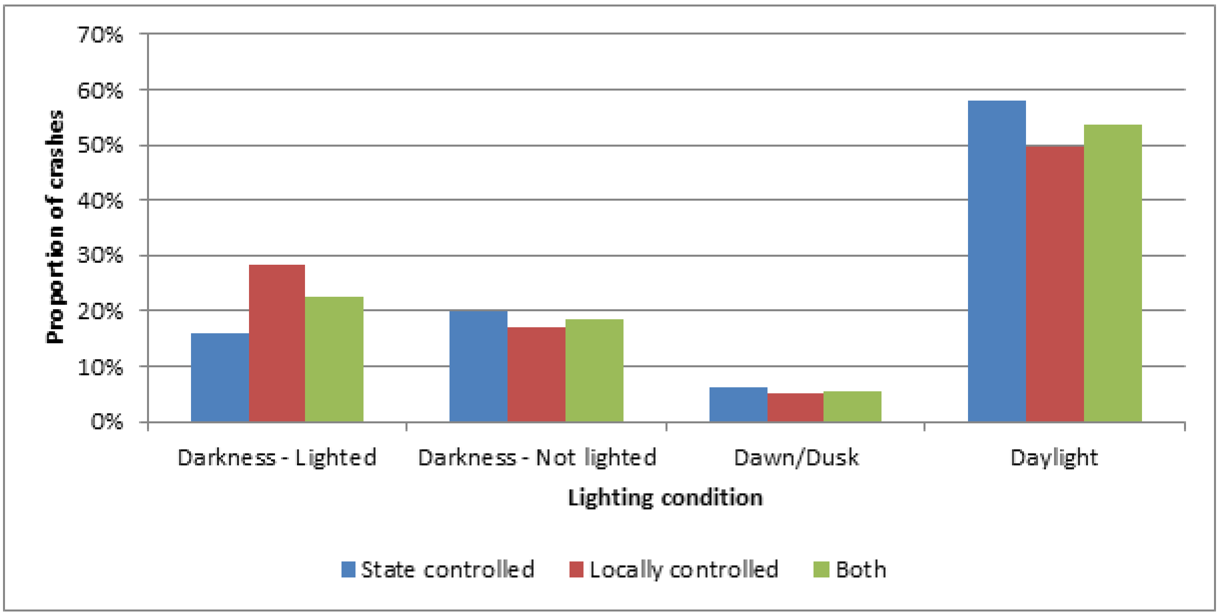
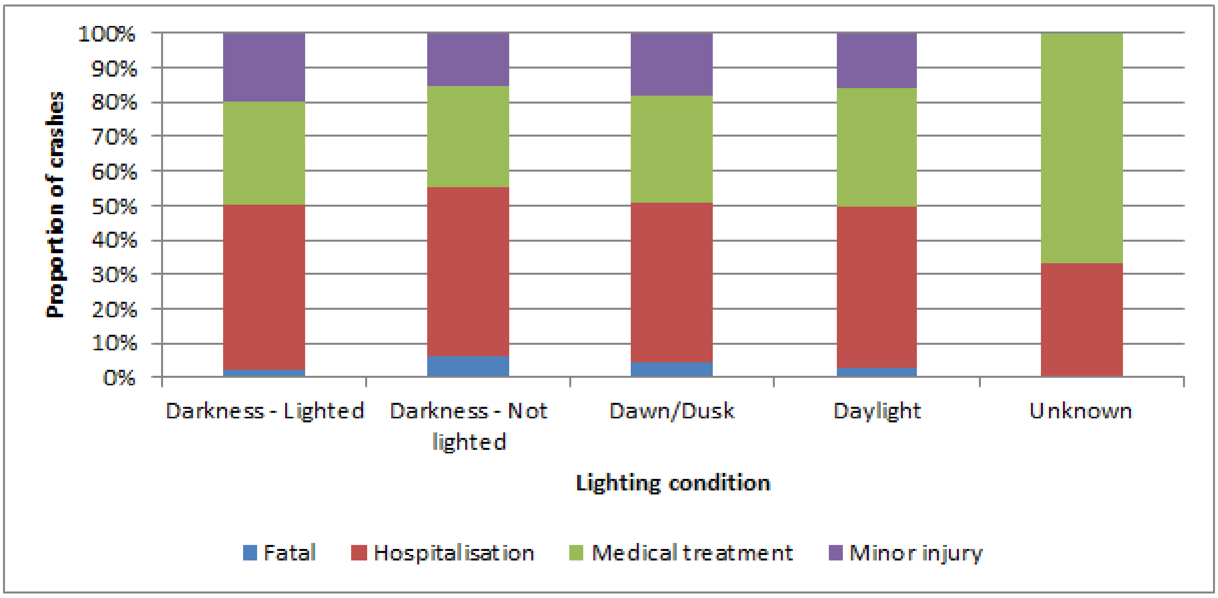


Figure 3.53 shows that the highest proportion of fatal and FSI for ROR crashes occurred during night time on roads with no lighting (darkness – not lighted).

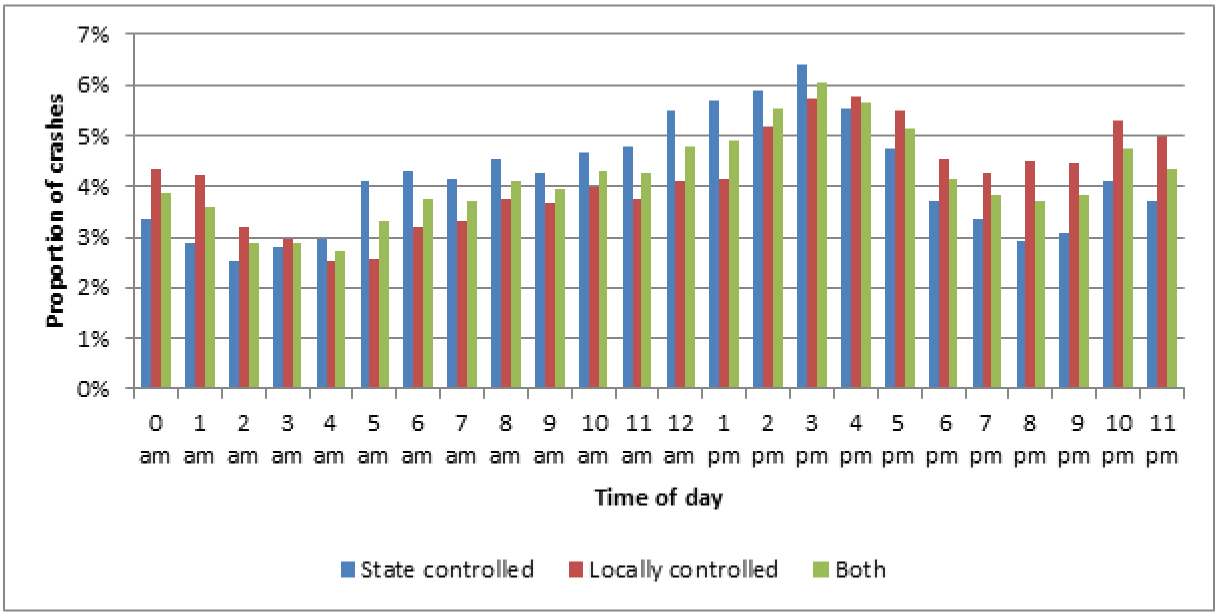
Figure 3.53: Run-off-road injury crashes by lighting condition and severity (2007-11)



3.4.8 Run-off-road Injury Crashes by Time of Day

The number of ROR injury crashes increased with time from 4 am before peaking at 3 pm and decreased gradually followed by a second peak between 10 pm and 2 am (Figure 3.54). The proportions of crashes during the morning peak (7-9 am) and evening peak (3-6 pm) were 12% and 17% respectively. These proportions are lower compared to all injury crashes. On the other hand, the proportion of ROR injury crashes from mid-night to 6 am is higher than all injury crashes (Figure 3.23).

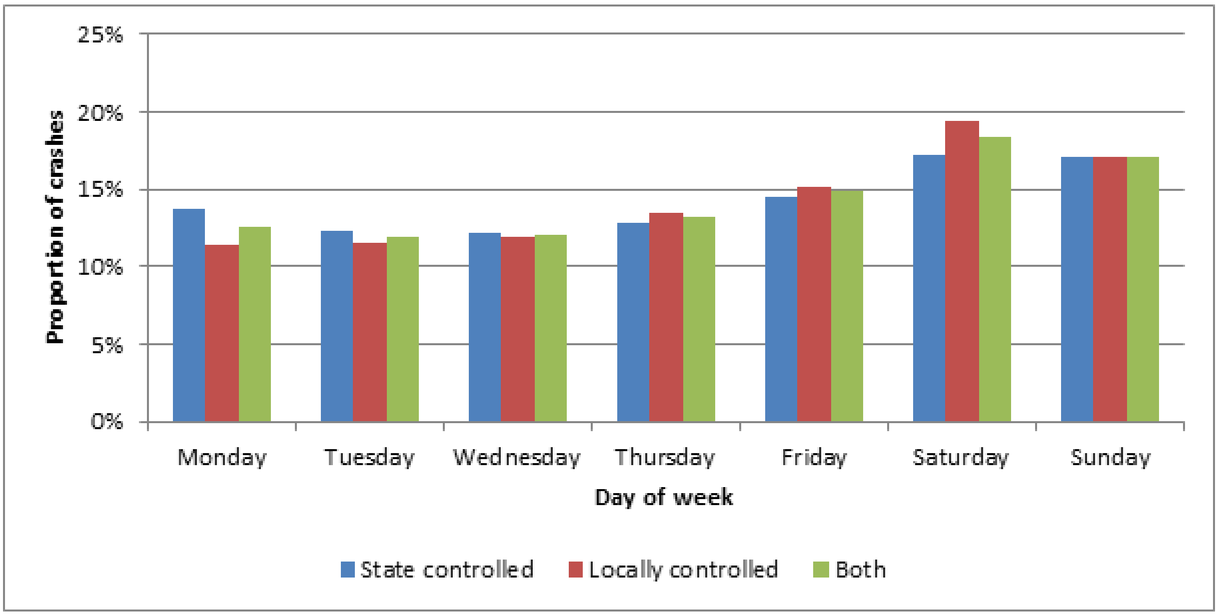
Figure 3.54: Run-off-road injury crashes by time of day (2007-11)



3.4.9 Run-off-road Injury Crashes by Day of week

Figure 3.55 shows the weekly pattern of ROR injury crashes. The largest proportion of ROR injury crashes occurred during the weekends, which is different from all injury crashes (Figure 3.25). The proportion of ROR injury crashes on weekends (35%) is significantly higher than that of all injury crashes (25%).

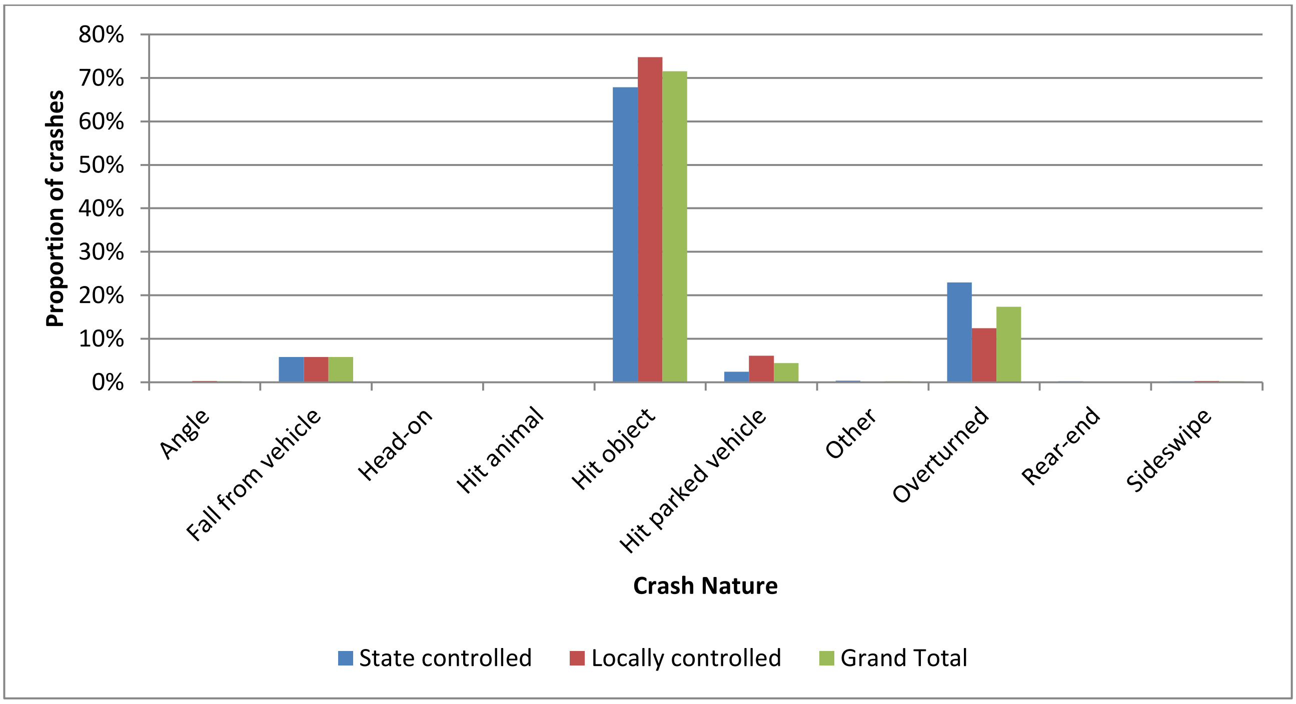
Figure 3.55: Run-off-road injury crashes by day of week (2007-11)



3.4.10 *Run-off-road Injury Crashes by Crash Nature*

Figure 3.56 shows the breakdown of ROR injury crashes by crash type. Most of the ROR crashes (72%) resulted in a collision with a roadside object and 17% resulted in overturned vehicle. There is the need to ensure there are no roadside hazards (i.e. cliff, non-frangible poles and objects, trees, deep drains, downward slopes, etc.) within the clear zone.

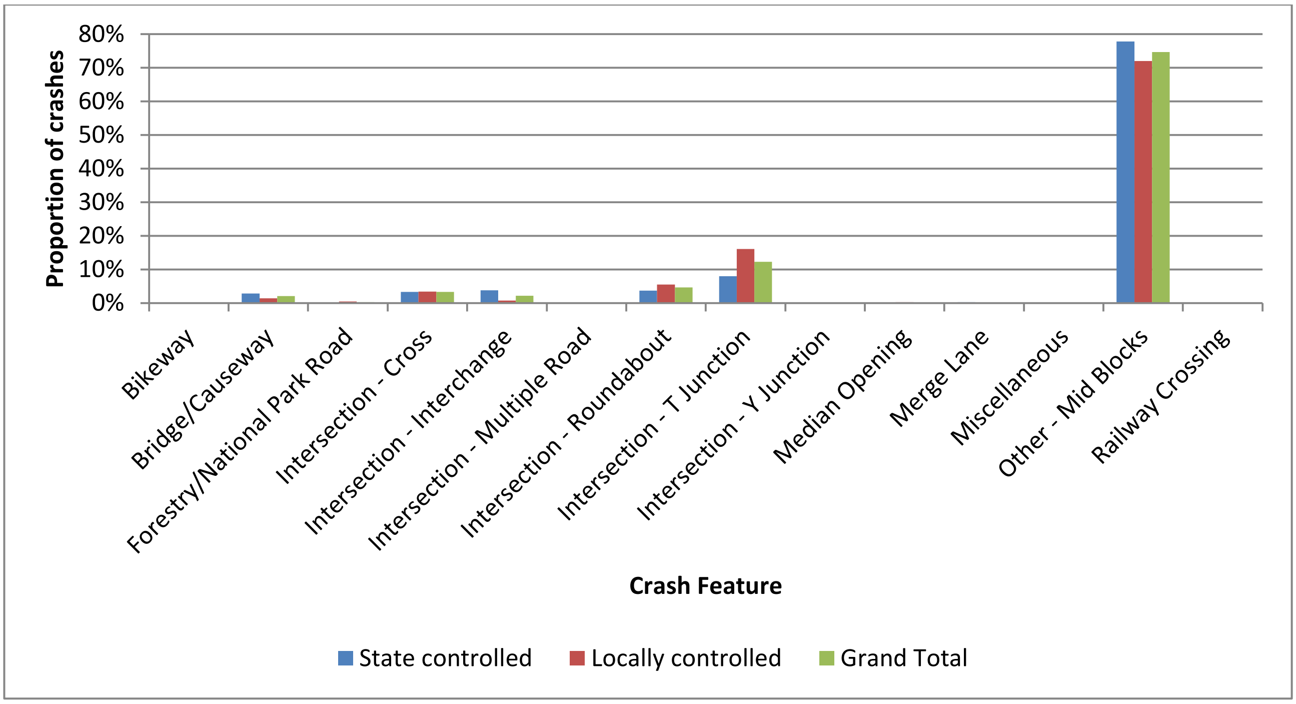
Figure 3.56: Run-off-road injury crashes by crash nature (2007-11)



3.4.11 Run-off-road Injury Crashes by Roadway Features

Figure 3.26 shows the proportion of ROR injury crashes by road feature. Most of the ROR injury crashes occurred at mid-block sections (75%). Most of the ROR injury crashes at intersections occurred at 3-leg intersections (52%).

Figure 3.57: Run-off-road injury crashes by crash feature (2007-11)

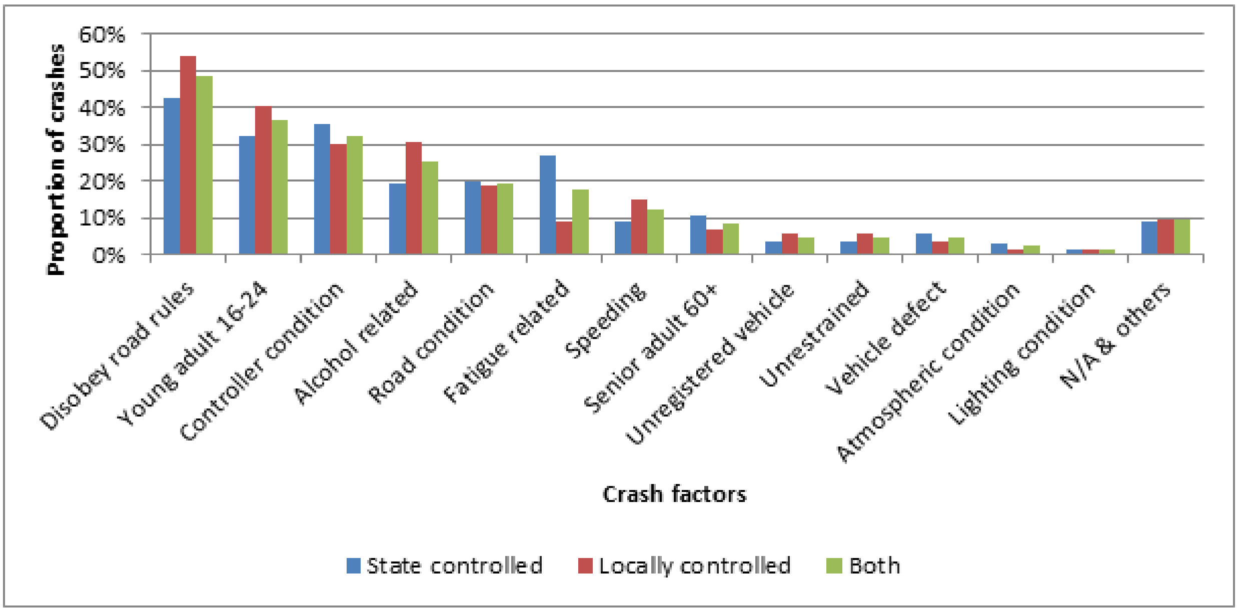


3.4.12 Run-off-road Injury Crashes by Crash Factors

Figure 3.58 shows the distribution of contributing crash factors in ROR injury crashes. Disobeying road rules (49%), young adult drivers between 16 and 24 years old (37%), controller condition (33%), alcohol related (25%) and road conditions were the top five main contributing factors.

On state-controlled roads, ‘fatigue related’ came in at four and was found to be a contributing factor in 27% of the ROR injury crashes.

Figure 3.58: Run-off-road injury crashes by crash factor (2007-11)



3.4.13 *Run-off-road Crashes by Primary Vehicle Controller Age*

Figure 3.59 shows the age groups of the primary vehicle controllers involved in ROR injury crashes. Young controllers 16-24 years old accounted for the highest proportion of ROR injury crashes (36%), followed by the 30-39 years age group (19%), the 25-29 years (13%) and 40-49 years age group (13%).

The risk for young controllers (less than 30 years) were higher on locally controlled roads compared to state-controlled roads. On the other hand, primary vehicle controllers 30 years and over had higher risk for ROR on state-controlled roads compared to local roads.

Figure 3.59: Run-off-road injury crashes by primary vehicle controller age (2007-11)

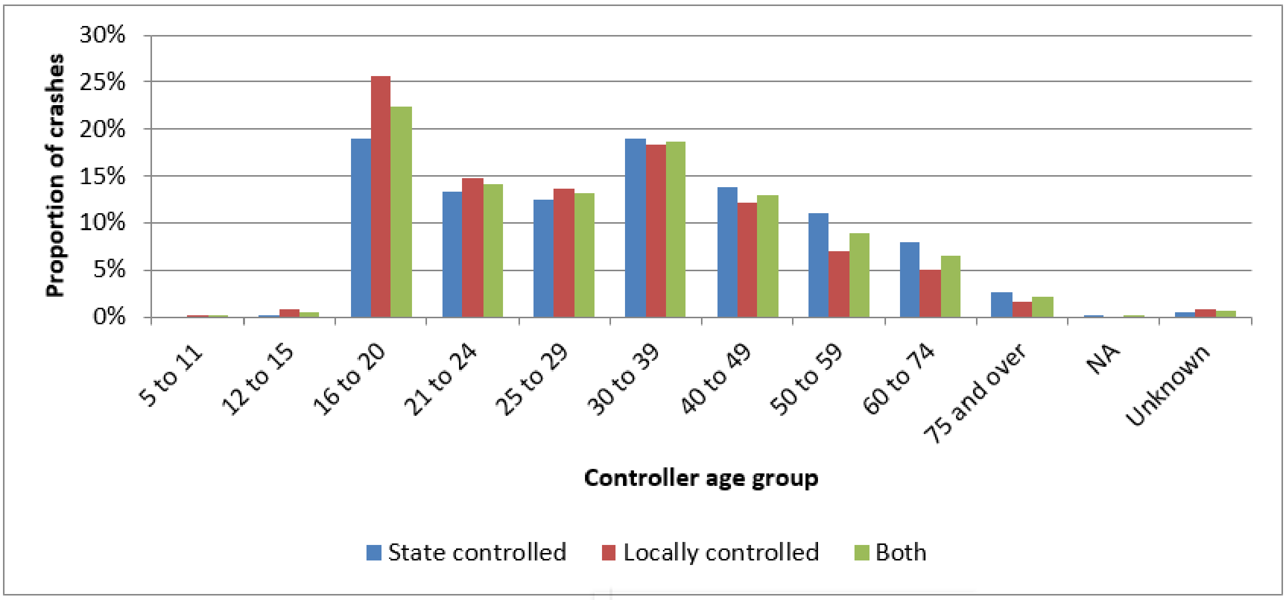
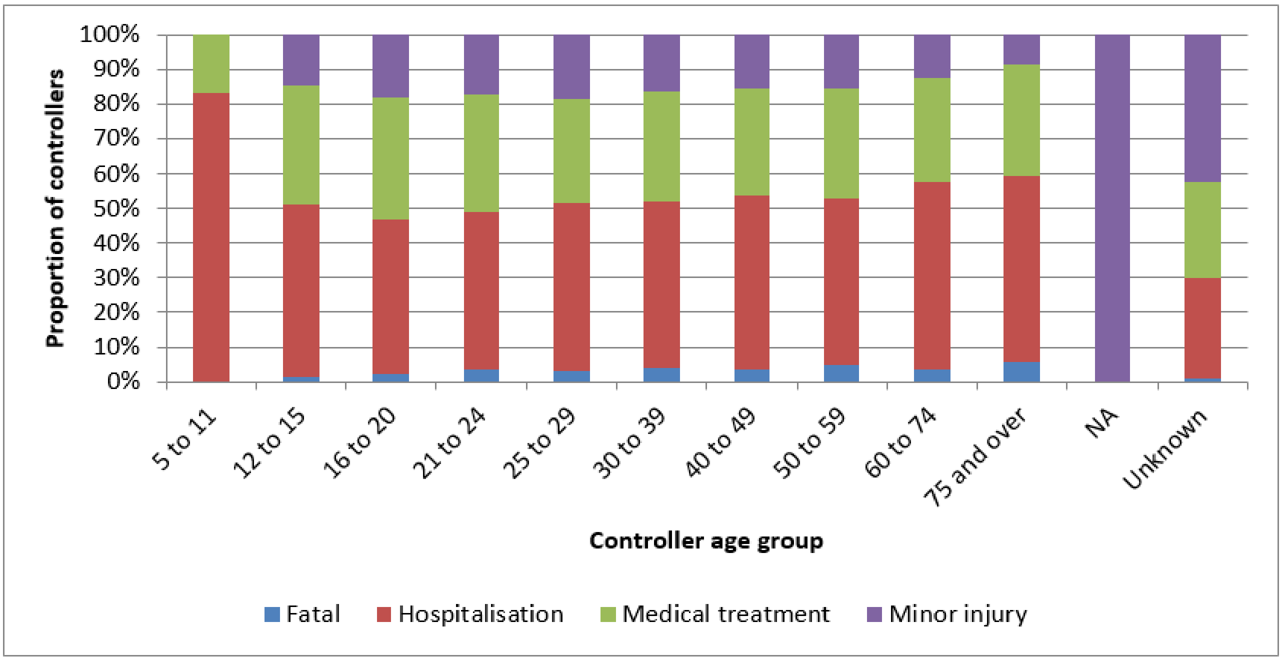


Figure 3.60 shows that the FSI proportion of run-off-road injury crashes generally increased as controller age increased, with the exception of 5 to 15 years age groups.

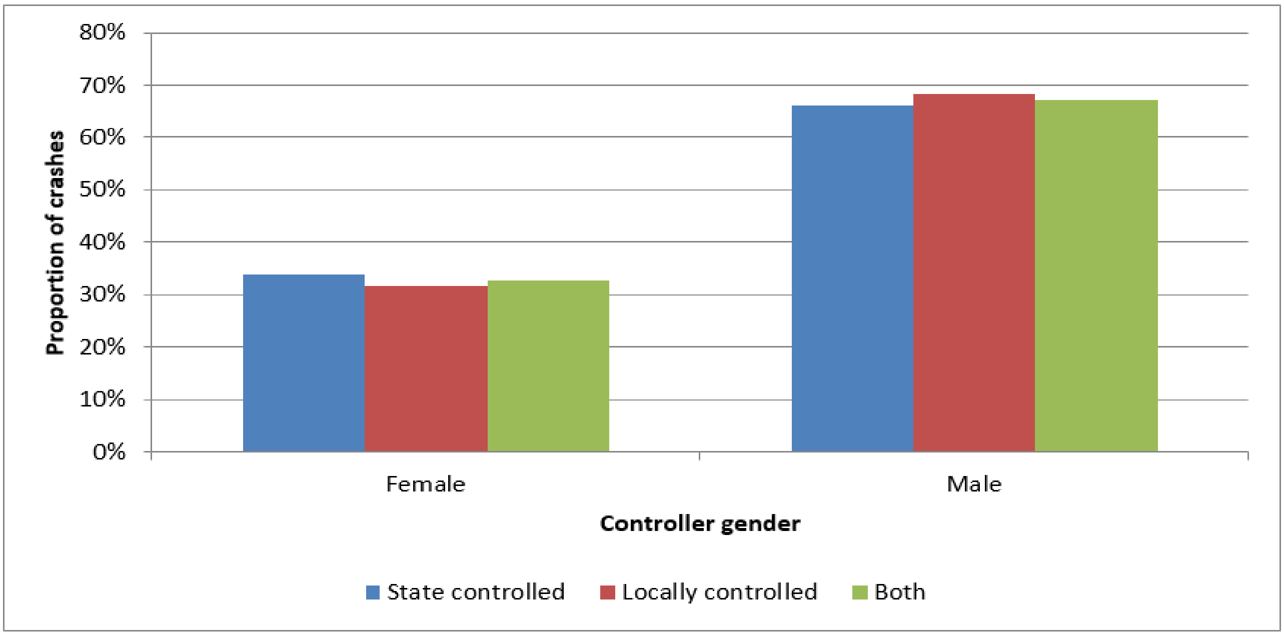
Figure 3.60: Run-off-road injury crashes by primary vehicle controller age and severity (2007-11)



3.4.14 Run-off-road crashes by Primary Vehicle Controller Gender

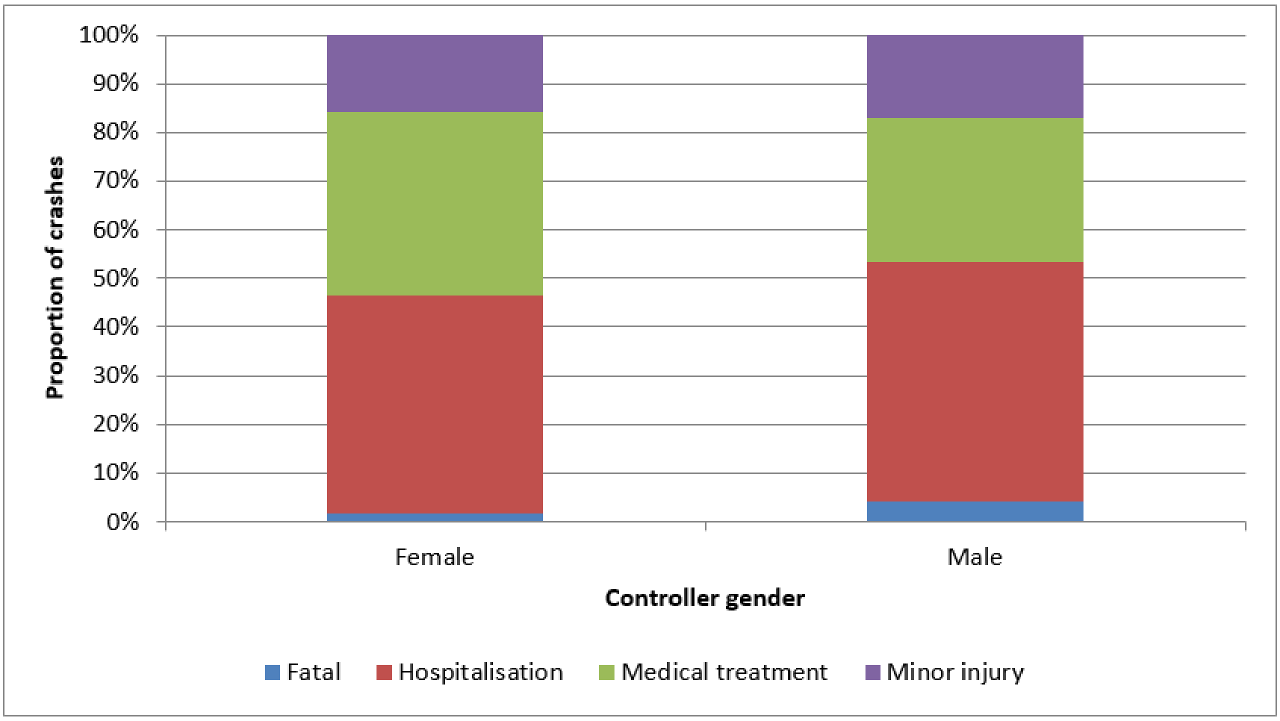
Figure 3.61 shows that male controllers of the primary vehicle accounted for about 67% of the ROR injury crashes (i.e. male controllers were twice as likely to be involved in ROR injury crashes compared to female controllers). There is only slight differences in the proportions of male and female controllers between state-controlled and locally controlled roads.

Figure 3.61: Run-off-road injury crash by primary vehicle controller gender (2007-11)



When involved in an ROR crash the risk of an FSI crash was higher for a male controller compared to a female controller (Figure 3.62).

Figure 3.62: Severity of run-off-road injury crash by primary vehicle controller gender (2007-11)



3.4.15 Run-off-road Crashes by Primary Vehicle Age

Figure 3.63 illustrates the breakdown of the age of the primary vehicles involved in ROR injury crashes. From 12 years onwards, there is a general reduction in ROR injury crash rate with vehicle age.

Vehicle age has no discernable impact of the severity of ROR (Figure 3.64)

Figure 3.63: Run-off-road injury crashes by primary vehicle age (2007-11)

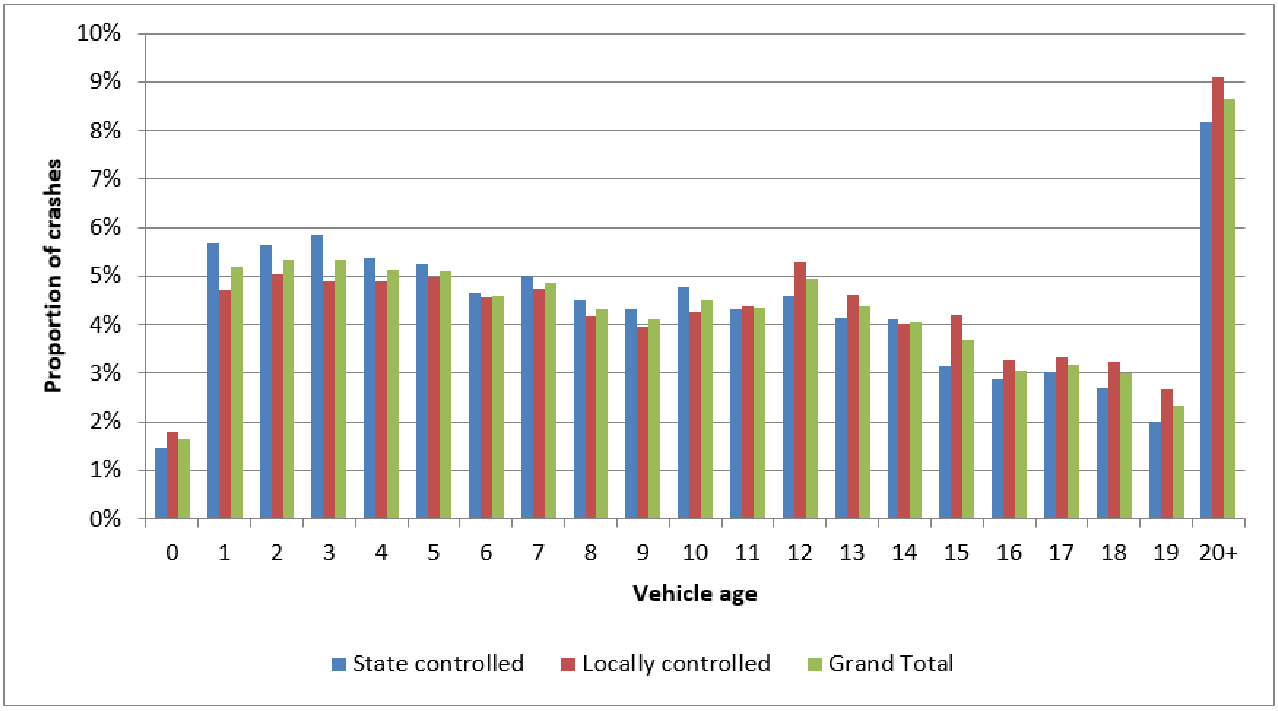
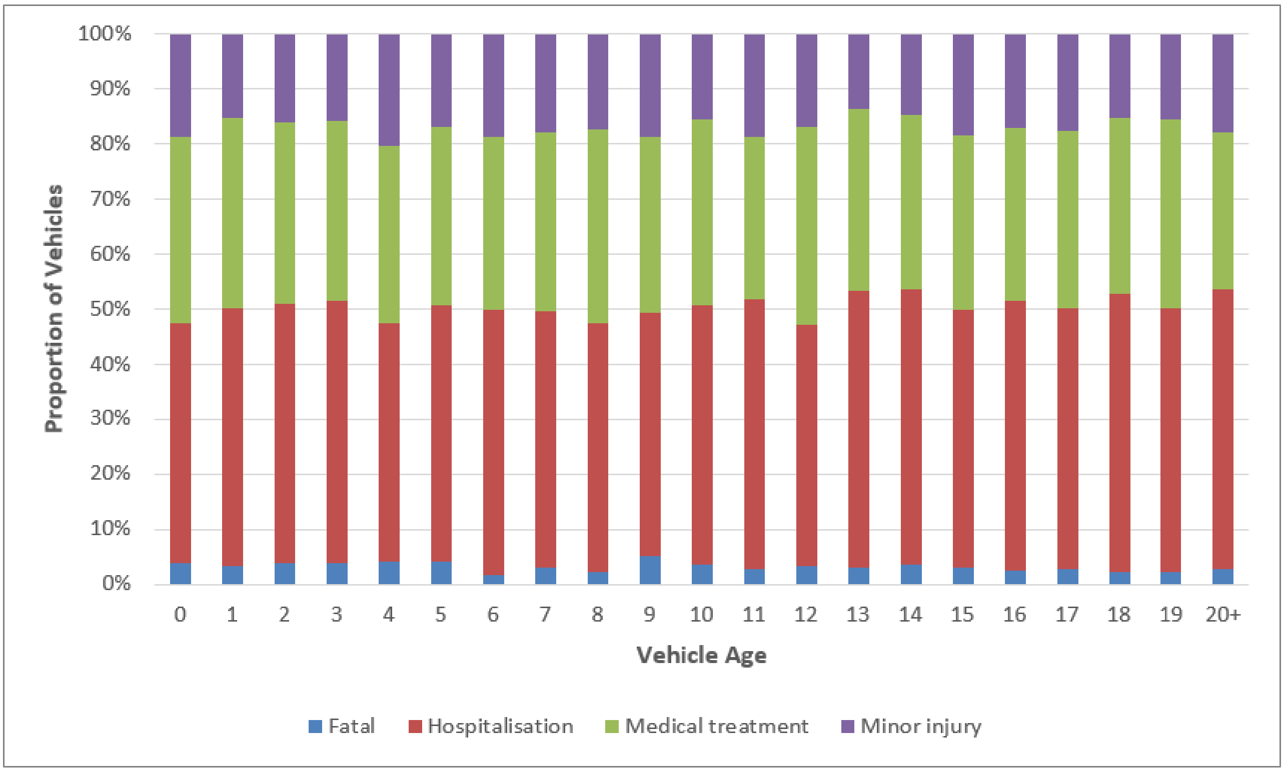


Figure 3.64: Severity of run-off-road crashes by primary vehicle age and (2007-11)



3.4.16 Run-off-road Crashes by Primary Vehicle Type

Figure 3.65 shows the primary vehicle types involved in ROR injury crashes. Light passenger vehicles make up the majority of the primary vehicles involved (85%), followed by motorcycles (9%) and heavy freight vehicles (4%).

By way of comparison, motorcyclists comprise less than 5% of the state's traffic, but constitute 9% of head-on injury crashes, hence they are over-represented in head-on crashes.

The proportion of heavy vehicles involved in ROR injury crashes was significantly higher on state-controlled roads than on locally controlled roads.

Figure 3.66 shows that motorcycles/mopeds (69%) and bicycles (59%) have the highest proportion of FSI crashes. Though the number of cyclists involved in run-off road crashes is small, they tend to be severe when they do happen, with cyclists recording the highest fatality rates when other vehicle types is excluded. About 9% of ROR crashes involving bicycles resulted in a fatality, higher than motorcycles at 7%.

Figure 3.65: Run-off-road crashes by primary vehicle type (2007-11)

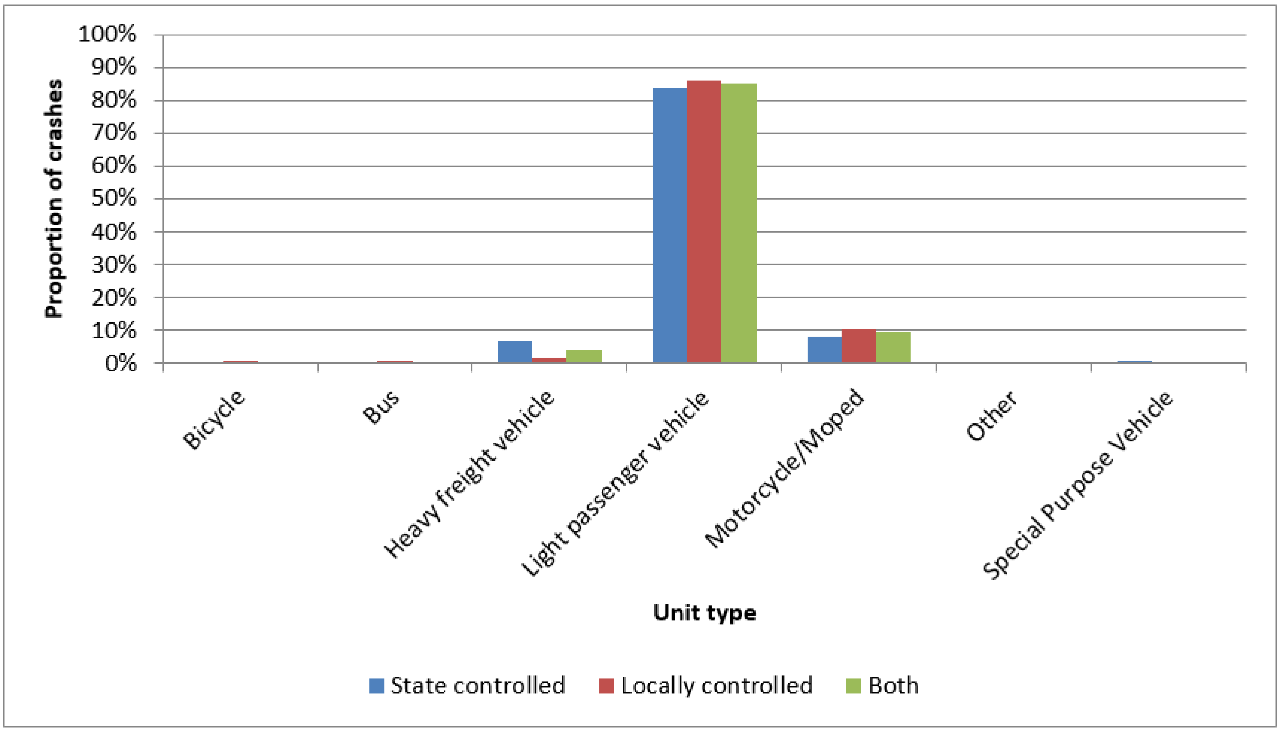
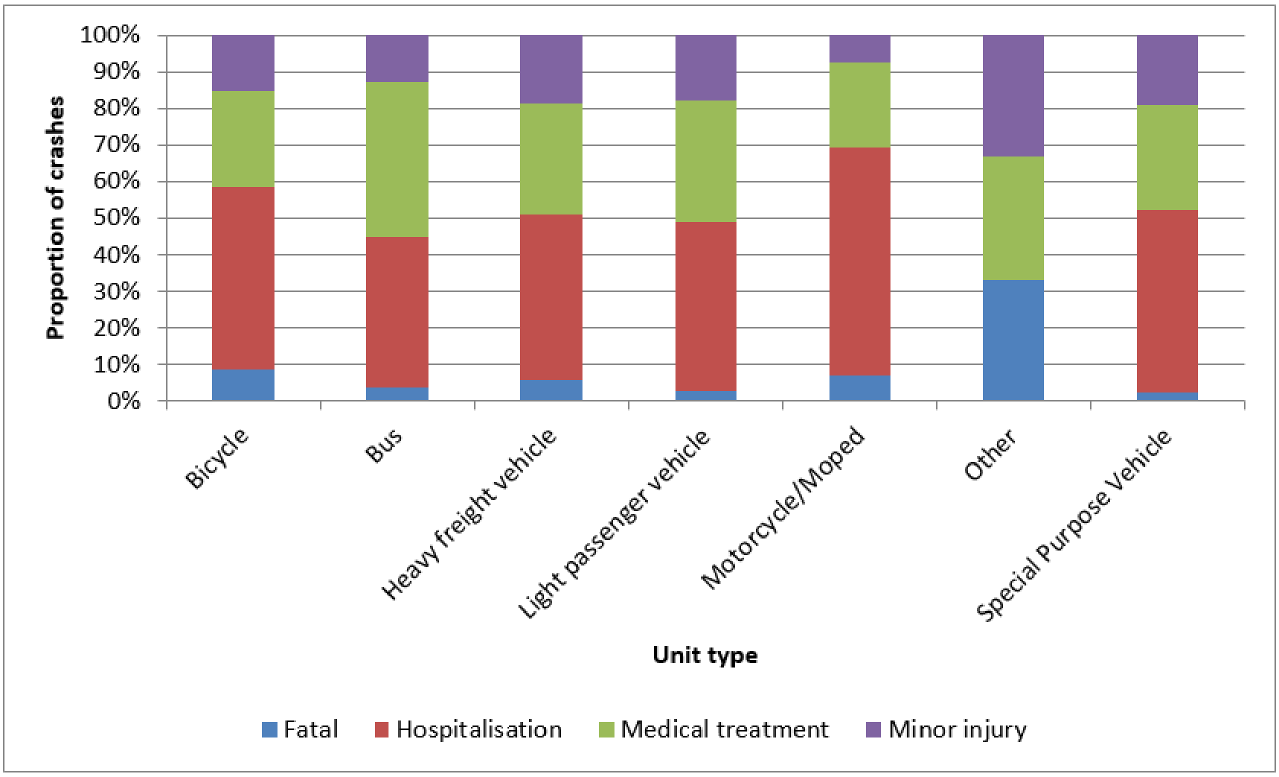


Figure 3.66: Severity of run-off-road crashes by primary vehicle type (2007-11)



3.4.17 Run-off-road High Crash Risk Sections – State-controlled Roads

State roads with high number of run-off-road crashes

Figure 3.67 shows the top 10 state-controlled road sections with the highest numbers of ROR injury crashes. These roads carry high traffic volume. The top three road sections in terms of ROR FSI crashes are 10A, 12A and 18A.

Table 3.8 shows the top 10 state-controlled roads with the highest ROR crash cost. The top 50 highest ROR crash cost roads are provided in Appendix B, Table B 1.

Figure 3.67: Run-off-road injury crashes by road and severity – road sections with highest numbers of crashes (2007-11)

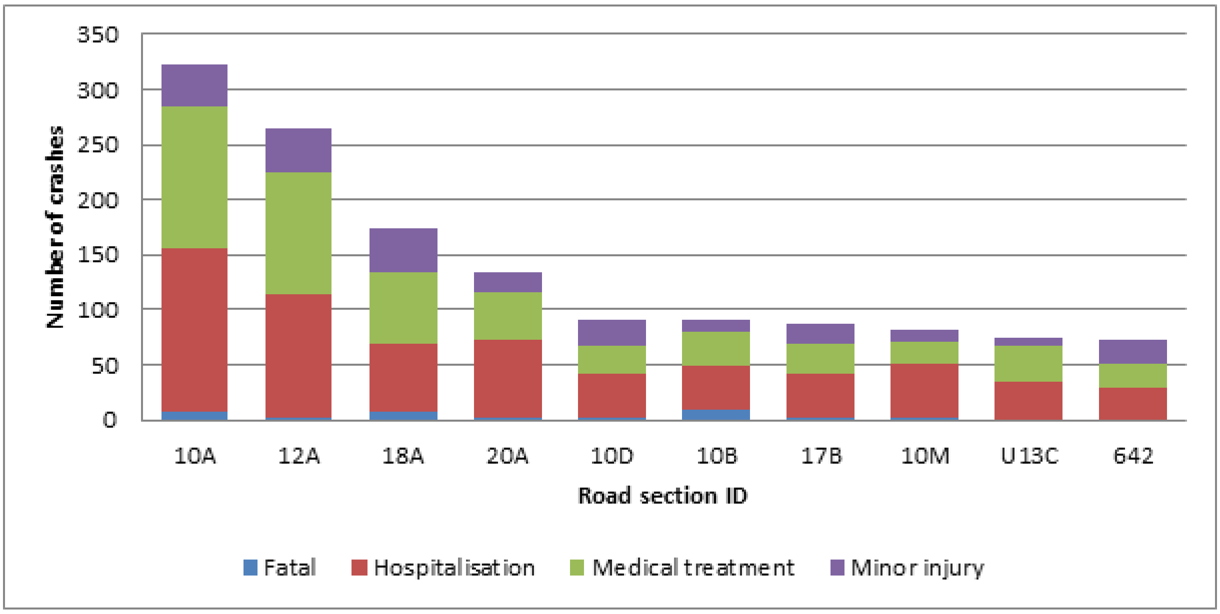


Table 3.8: Top 10 state-controlled roads with the highest run-off-road injury crashes by crash cost (2007-11)

Road Sections	Fatal – ROR crashes	Hospitalisation – ROR crashes	Medical treatment – ROR crashes	Minor injury – ROR crashes	Total – ROR crashes	Annual average ROR crash cost
10A	8	148	128	39	323	$26,895,222
10B	10	39	31	10	90	$19,886,539
18A	8	61	65	41	175	$19,199,130
12A	3	112	110	40	265	$15,737,020
20A	3	70	43	18	134	$11,065,120
202	5	19	13	6	43	$9,860,829
10J	5	18	11	1	35	$9,706,970
120	5	17	10	3	35	$9,627,614
10G	4	32	23	13	72	$9,449,254
10P	4	27	17	9	57	$8,924,849

Run-off-road collective risk for state-controlled roads

The top 10 high collective risk state-controlled road sections for ROR injury crashes ranked by crash cost per km are shown in Table 3.9. The top 50 high collective ROR crash risk road sections are provided in Appendix B, Table B 2.

Table 3.9: Top 10 state-controlled roads with the highest run-off-road crash cost per km (collective risk), 2007-11

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total ROR injury crashes	Total ROR FSI crashes	Annual average ROR injury crashes per km	Annual average ROR injury crash cost per km	Annual average ROR injury crashes per 100M veh-km	Annual average ROR injury crash cost per 1000 veh-km
120	17.83	29741	35	22	0.393	$539,967	3.62	$50.00

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total ROR injury crashes	Total ROR FSI crashes	Annual average ROR injury crashes per km	Annual average ROR injury crash cost per km	Annual average ROR injury crashes per 100M veh-km	Annual average ROR injury crash cost per 1000 veh-km
U18A	10.95	29779	22	6	0.402	$344,252	3.70	$32.00
U20	7.41	27402	21	9	0.567	$326,061	5.67	$32.00
103	17.92	38171	45	27	0.502	$303,169	3.61	$22.00
210A	29.03	NA	60	35	0.413	$265,570	NA	NA
9905	8.24	13604	16	6	0.388	$261,395	7.82	$52.00
206	22.11	6063	42	22	0.38	$231,715	17.17	$104.00
U14	14.31	41829	34	19	0.475	$225,407	3.11	$14.00
U15	11.87	29421	30	10	0.505	$221,797	4.71	$20.00
153	12.73	35631	25	13	0.393	$212,783	3.02	$16.00

Run-off-road individual risk for state-controlled roads

The top 10 high individual risk state-controlled road sections for ROR crashes by crash cost per VKT are shown in Table 3.10. The road sections consist of those that carry very low traffic volume. The top 50 high individual ROR crash risk road sections are provided in Appendix B, Table B 3.

Table 3.10: Top 10 state-controlled roads with high run-off-road crash cost per VKT, 2007-11 (individual risk)

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total ROR injury crashes	Total ROR FSI crashes	Annual average ROR injury crashes per km	Annual average ROR injury crash cost per km	Annual average ROR injury crashes per 100M veh-km	Annual average ROR injury crash cost per 1000 veh-km
6404	10.72	579	9	6	0.168	$337,194	79.46	$1,596.00
5109	17.88	15	1	1	0.011	$4,091	204.30	$748.00
2134	14.37	894	7	4	0.097	$131,211	29.87	$402.00
8554	11.27	179	6	3	0.107	$23,951	163.50	$368.00
475	55.67	299	11	2	0.04	$33,297	36.23	$306.00
232	99.18	207	10	7	0.02	$21,502	26.65	$284.00
4981	10.5	1899	9	3	0.171	$178,714	24.74	$258.00
3341	4.67	178	1	1	0.043	$15,664	66.10	$242.00
1204	13.86	2137	14	9	0.202	$165,514	25.90	$212.00
4023	27.11	429	19	11	0.14	$32,939	89.45	$210.00

3.5 Out-of-control Crashes

This section details the characteristics of out-of-control injury crashes. They included crashes defined in the crash database as ‘loss of control on carriageway’. The DCA codes and their definitions included in the out-of-control (OOC) crash data analysis are shown in Table 3.11.

Out of the 69 533 injury crashes reported on Queensland roads between 2007 and 2011, 3 265 were out-of-control crashes. This accounted for 5% of all injury crashes and 6% of FSI crashes in the five year period. On state-controlled roads, out-of-control crashes accounted for 5% of injury crashes and 7% of FSI crashes between 2007 and 2011.

Table 3.11: Out-of-control crashes

DCA Code	Fatal	Hospitalisation	Medical treatment	Minor injury	Total
705	34	866	562	265	1727
805	47	779	508	204	1538
Total	81	1645	1070	469	3265

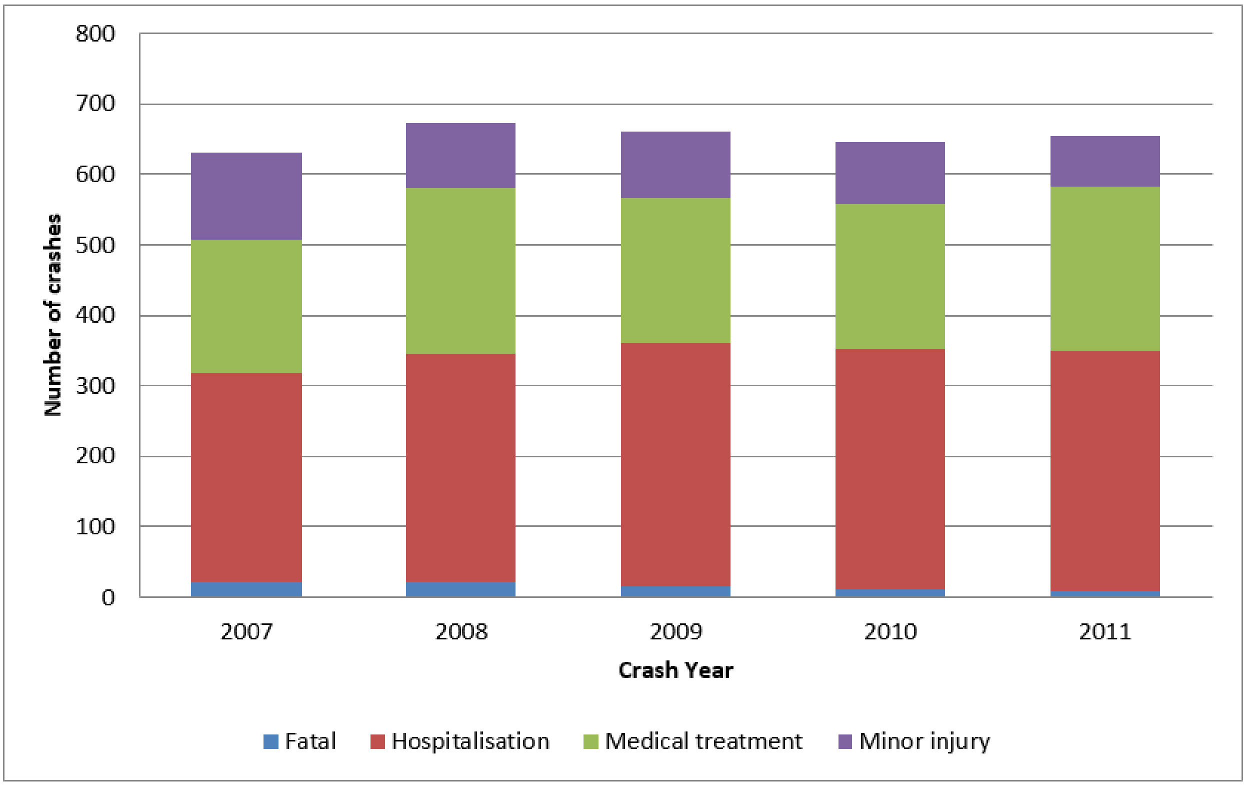
Notes

- DCA code 705 – Off path on straight, out-of-control on carriageway
- DCA code 805 – Off path on curve, out-of-control on carriageway

3.5.1 Annual Distribution of Out-of-Control Crashes

Figure 3.68 shows the annual OOC injury crashes from 2007 to 2011. There was a 55% reduction in fatal OOC crashes from 22 fatal crashes in 2007 to 10 in 2011, but an increase of 10% in out-of-control FSI crashes was observed. The FSI crashes peaked at 361 in 2009.

Figure 3.68: Out-of-control injury crashes by year and severity (2007-11)

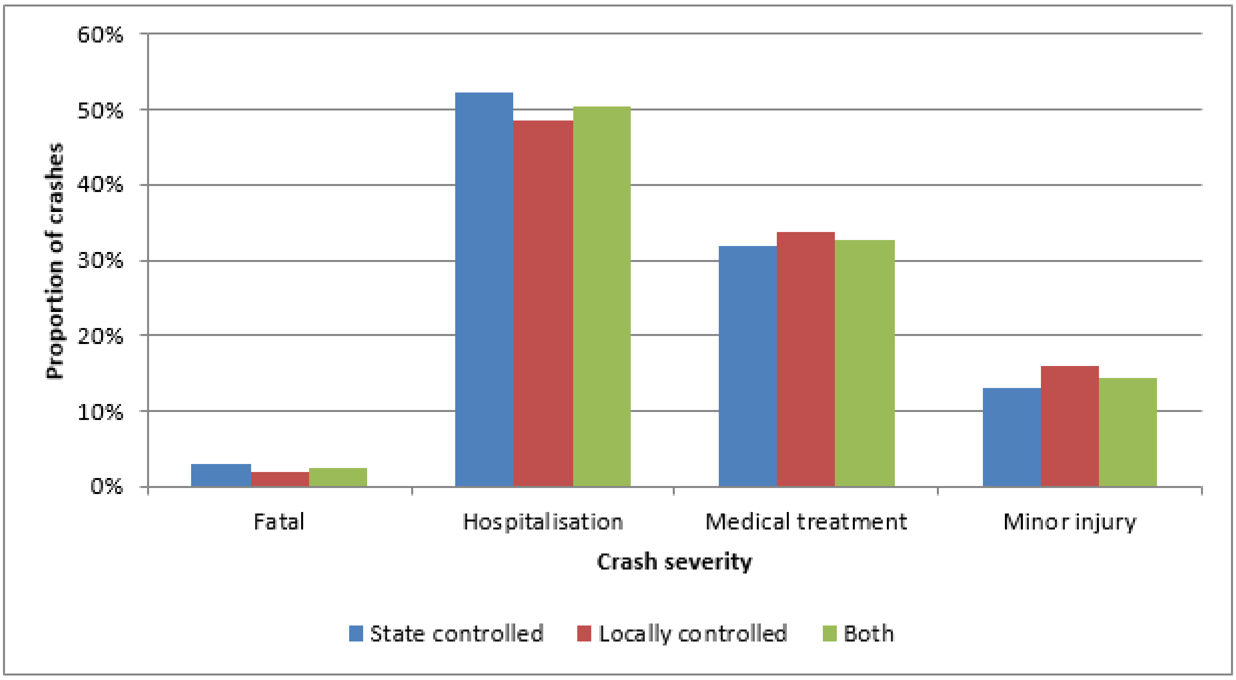


3.5.2 Out-of-control Crash Severity

State-controlled roads accounted for approximately 52% of the OOC injury crashes. About 3% of OOC crashes on state-controlled roads were fatal crashes, slightly higher than on locally controlled roads (2%).

A higher proportion of fatalities and hospitalisations occurred in OOC crashes compared to other crash types. About 52% of OOC injury crashes were FSI crashes compared to 40% observed for all injury crashes (Figure 3.69).

Figure 3.69: Out-of-control injury crashes by road authorities and severity (2007-11)



3.5.3 *Out-of-control Injury Crashes by Posted Speed Limit*

Figure 3.70 shows that the majority of OOC crashes on locally-controlled roads occurred in 0-60 km/h posted speed limit zones whilst on the state-controlled roads most of the OOC injury crashes occurred in the 100-110 km/h posted speed limit zones.

Overall, 55% of the OOC injury crashes occurred on the high speed roads (80 km/h or more). This is significantly higher than the 27% recorded for all injury crashes. The proportion of fatal and FSI crashes generally increased with increasing posted speed limit (Figure 3.71).

Figure 3.70: Out-of-control injury crashes by posted speed limit (2007-11)

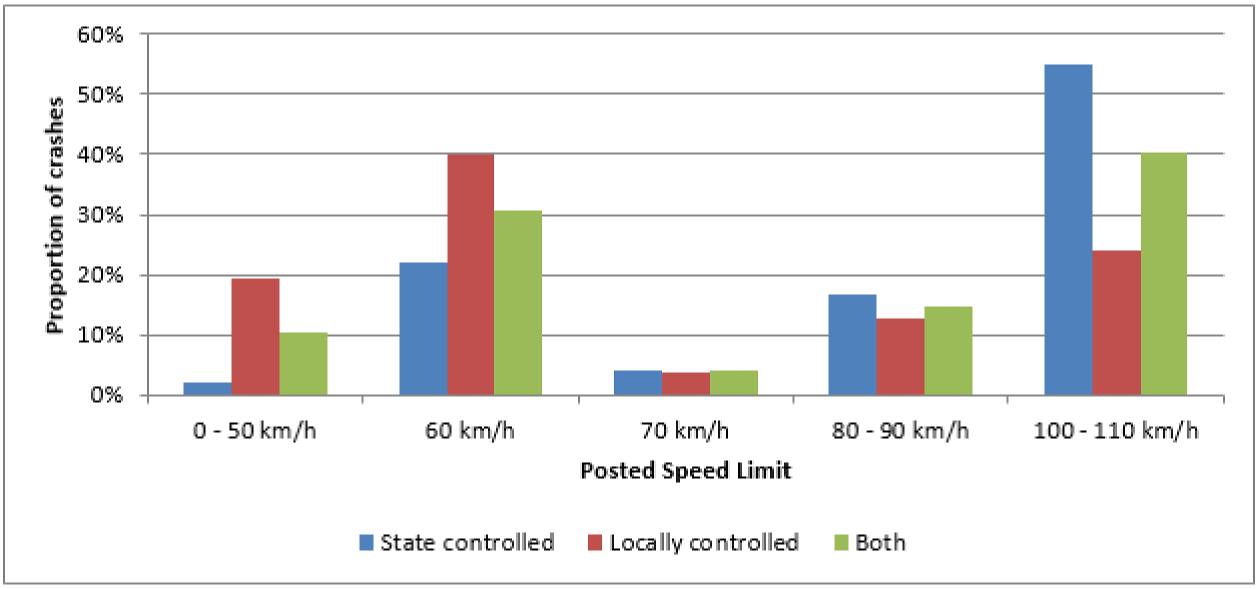
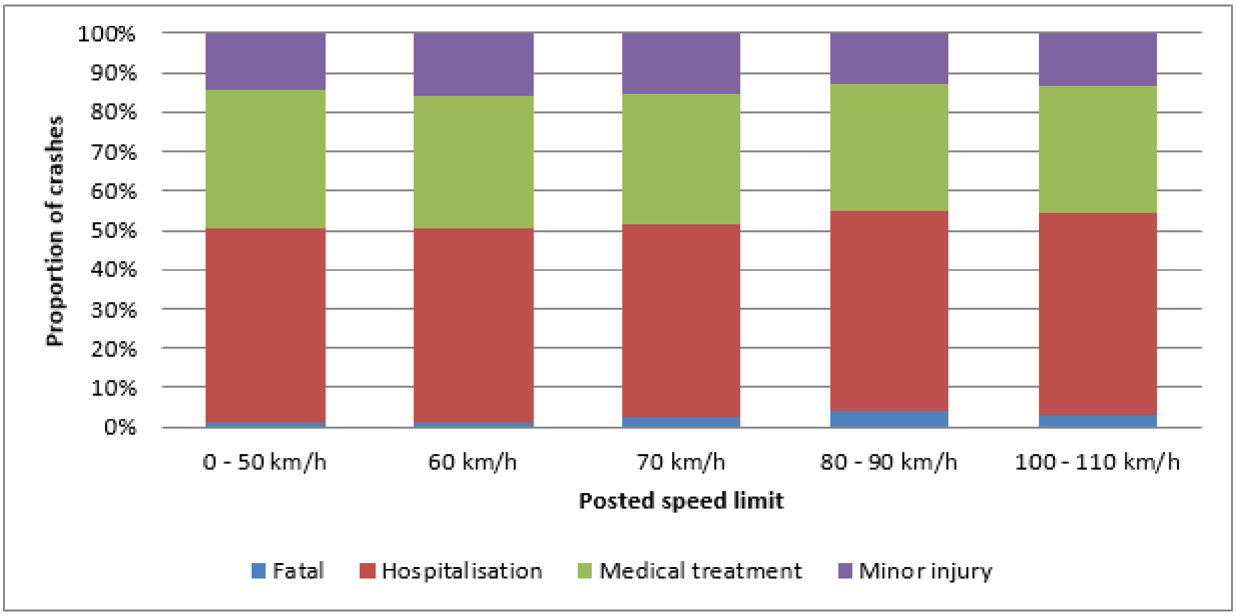


Figure 3.71: Out-of-control injury crashes by posted speed limit and severity (2007-11)



3.5.4 *Out-of-control Injury Crashes by Horizontal Alignment*

Figure 3.72 shows that about 47% of OOC injury crashes occurred on curves. This proportion is significantly higher than the 23% for all injury crashes that occurred on curves.

The proportions of OOC crashes that resulted in FSI crashes were similar on curved and straight sections (Figure 3.73). However, the proportion of fatalities was slightly higher on curved road sections than on the straight sections (3% compared to 2%).

Figure 3.72: Out-of-control injury crashes by horizontal alignment (2007-11)

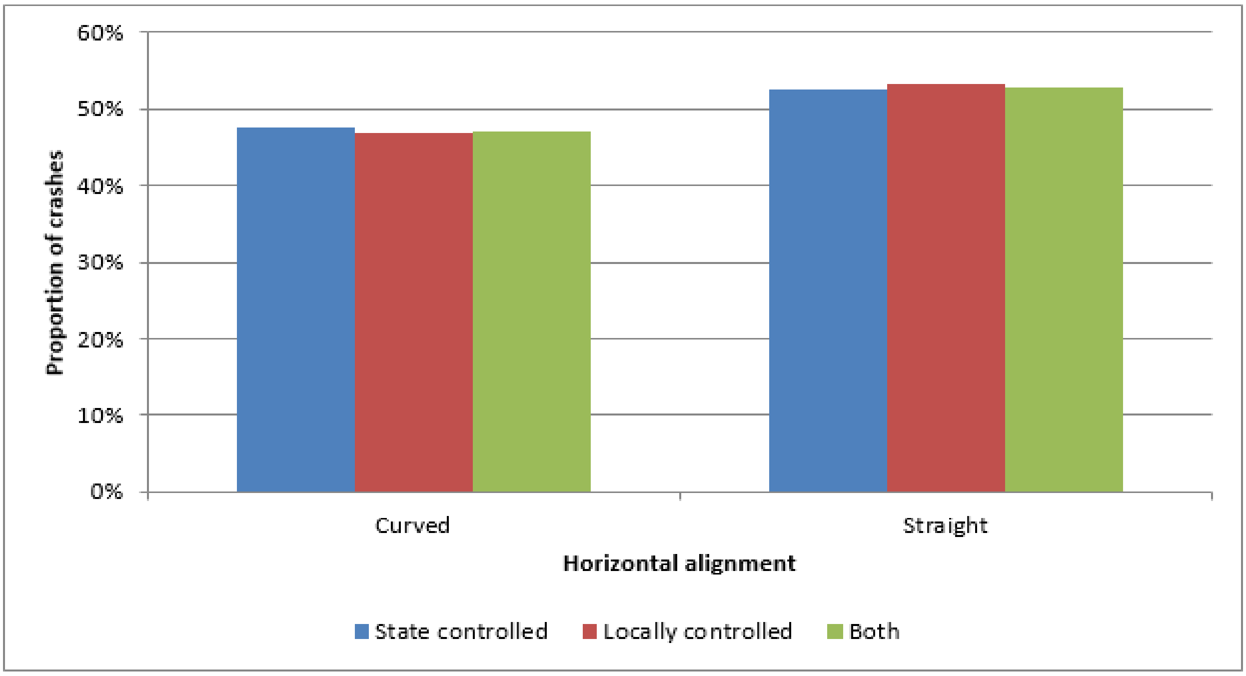
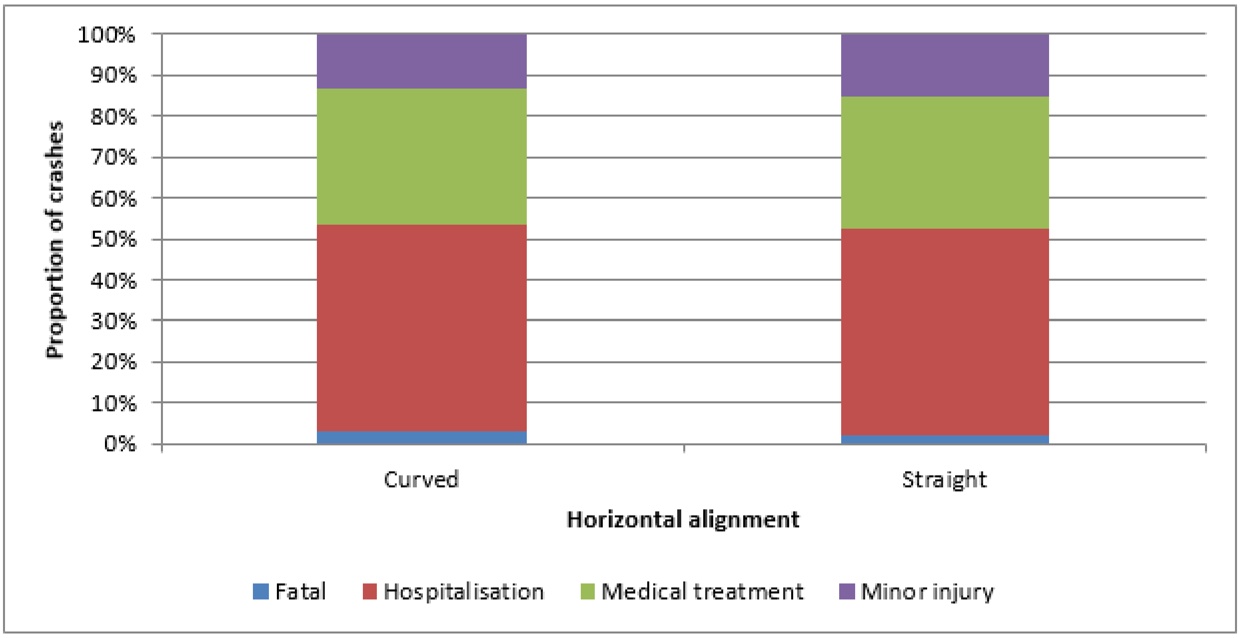


Figure 3.73: Out-of-control injury crashes by horizontal alignment and severity (2007-11)



3.5.5 *Out-of-control Injury Crashes by Vertical Alignment*

Figure 3.74 shows that about 36% of OOC injury crashes occurred on a grade, dip or crest. This is higher than the 25% recorded for all injury crashes.

Figure 3.75 shows that the proportion of FSI crashes was marginally lower on grade compared to crest, dip and level road. However grade recorded the highest proportion of fatalities.

Figure 3.74: Out-of-control injury crashes by vertical alignment (2007-11)

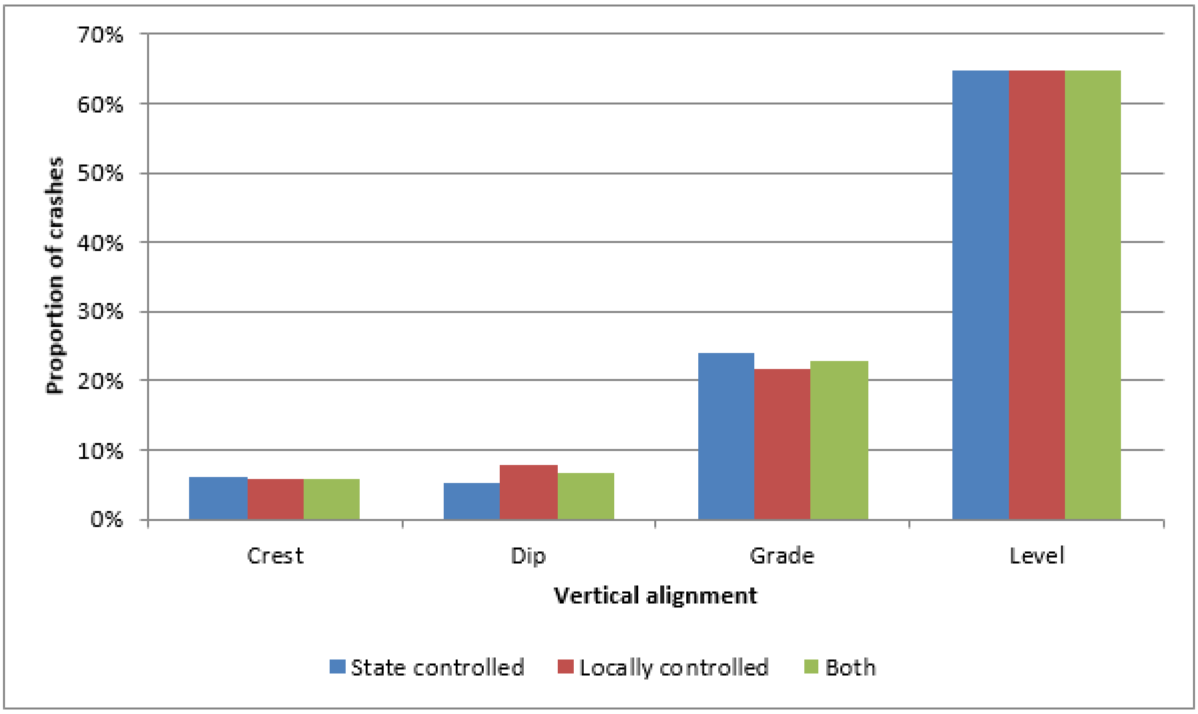
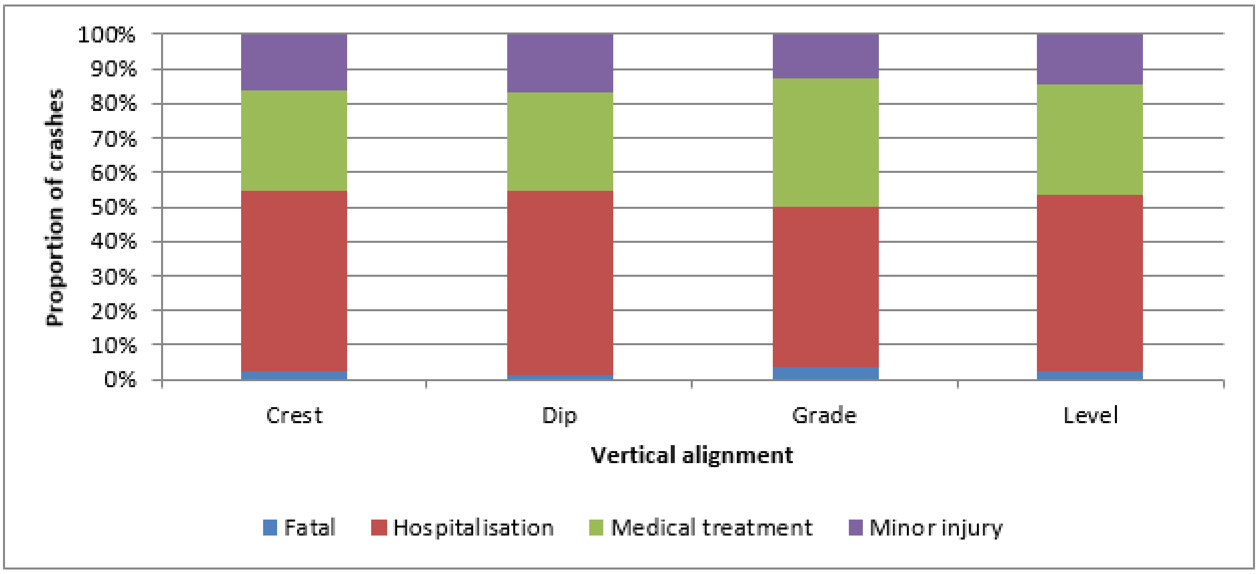


Figure 3.75: Out-of-control of carriageway injury crashes by vertical alignment and severity (2007-11)



3.5.6 *Out-of-control Injury Crashes by Road Surface Condition*

Figure 3.76 shows that about 16% of OOC injury crashes occurred on wet road surfaces, similar to the proportion for all injury crashes. This implies wet weather may have little or no impact on the occurrence of this crash type.

Unsealed sections accounted for about 13% of the OOC injury crashes significantly more than the proportion of all injury crashes on unsealed roads (3%).

Figure 3.76: Out-of-control injury crashes by road surface condition (2007-11)

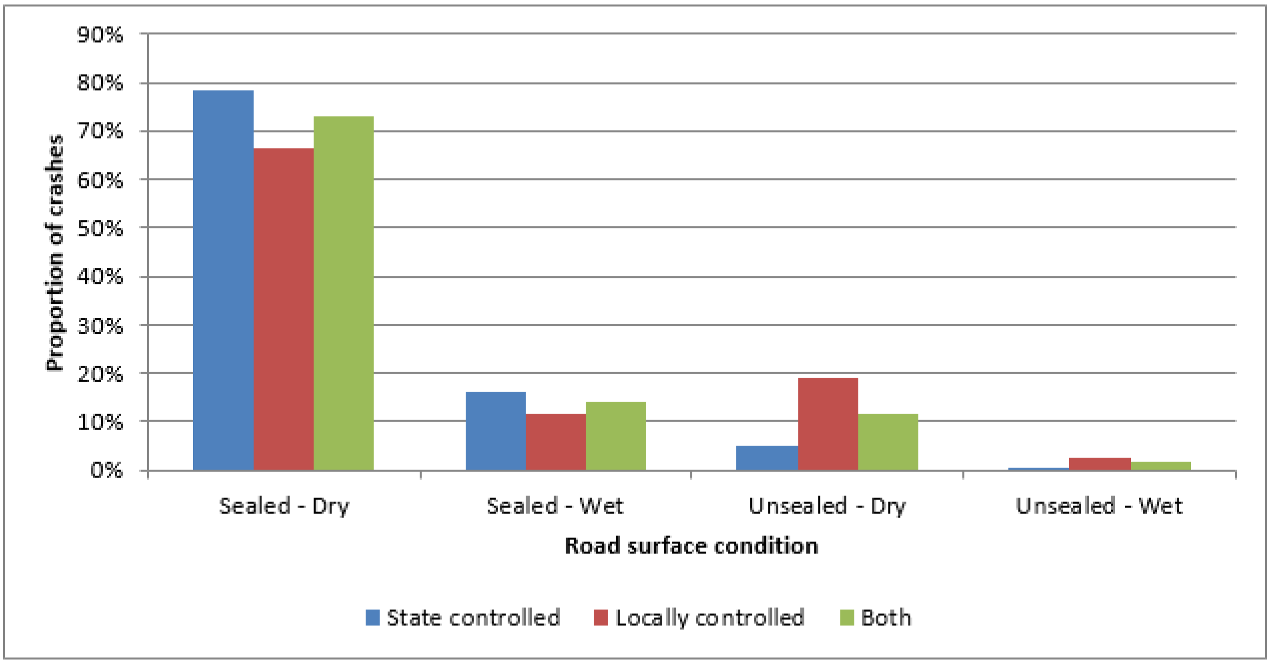
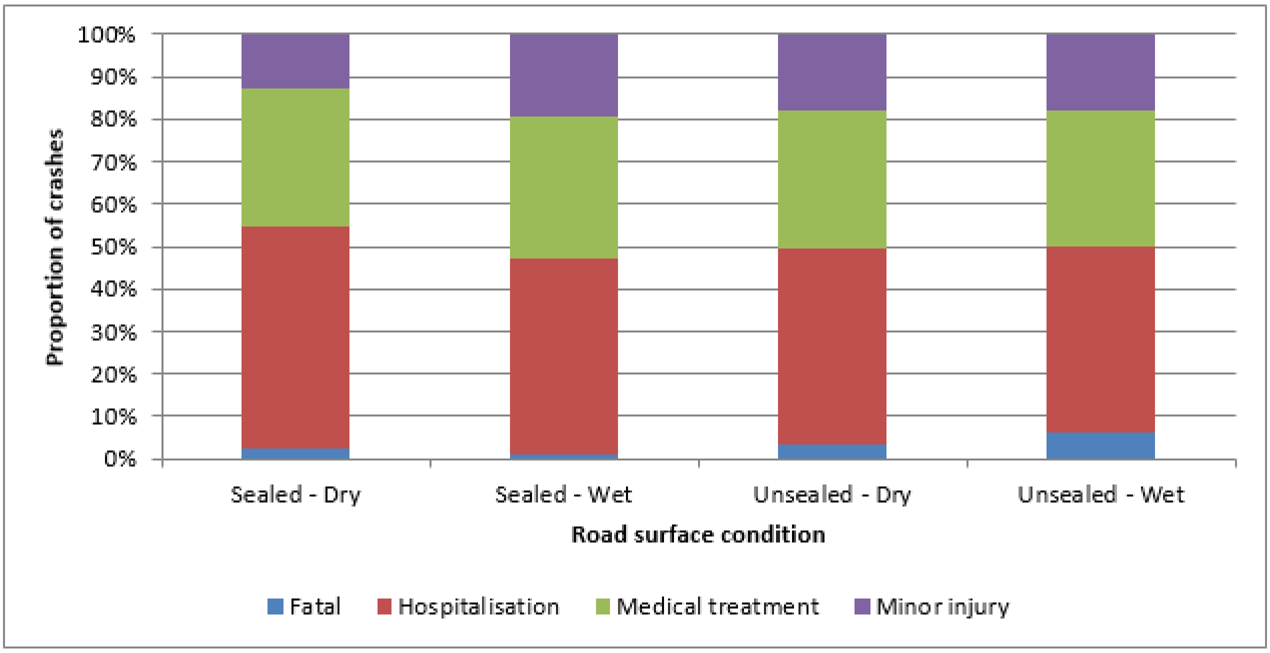


Figure 3.77 shows that dry sealed surfaces recorded the highest proportion of FSI out-of-control crashes. For sealed roads, the risk of an FSI out-of-control crash was higher on dry surfaces than wet road condition.

Figure 3.77: Out-of-control injury crashes by road surface condition and severity (2007-11)



3.5.7 *Out-of-control Injury Crashes by Lighting Condition*

Figure 3.78 clearly shows that the majority of OOC injury crashes (65%) occurred in daylight. The proportion that occurred during daylight is slightly higher on state-controlled roads (66%) than on locally controlled roads (63%). The 35% of OOC injury crashes that occurred during adverse lighting condition is higher than the 30% for all injury crashes.

Figure 3.79 shows that severity of night-time OOC crashes was higher than daylight ones. Night-time OOC crashes on roads with no lighting recorded the highest proportion of FSI crashes.

Figure 3.78: Out-of-control injury crashes by lighting condition (2007-11)

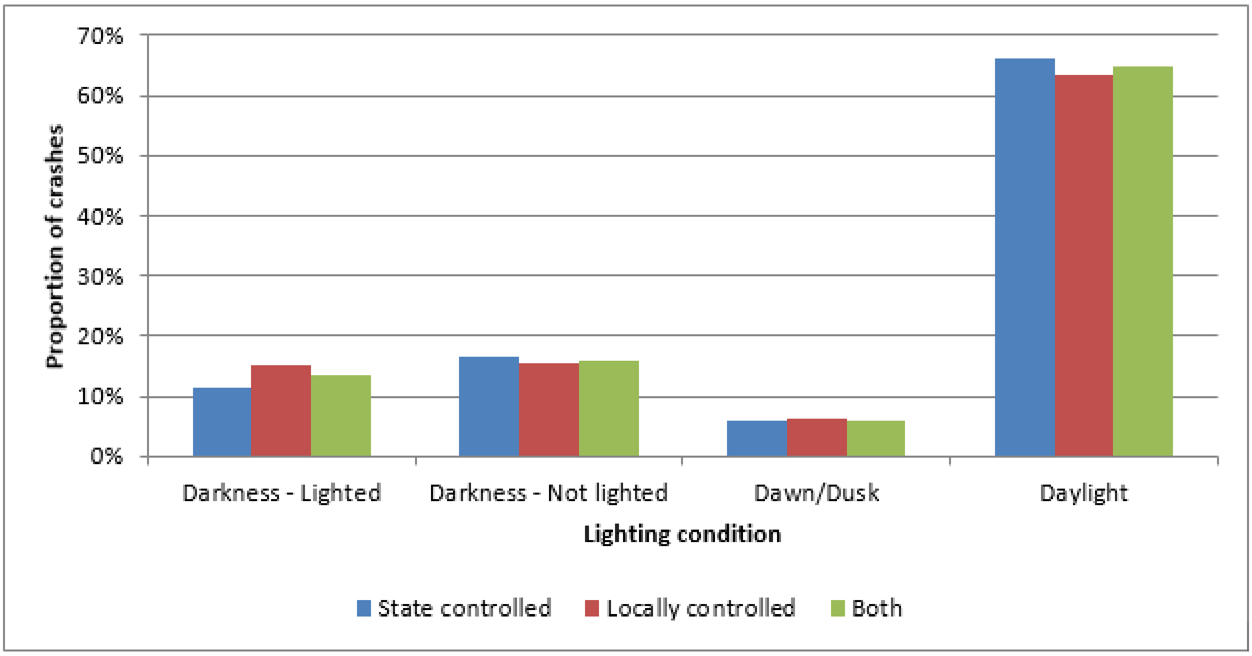
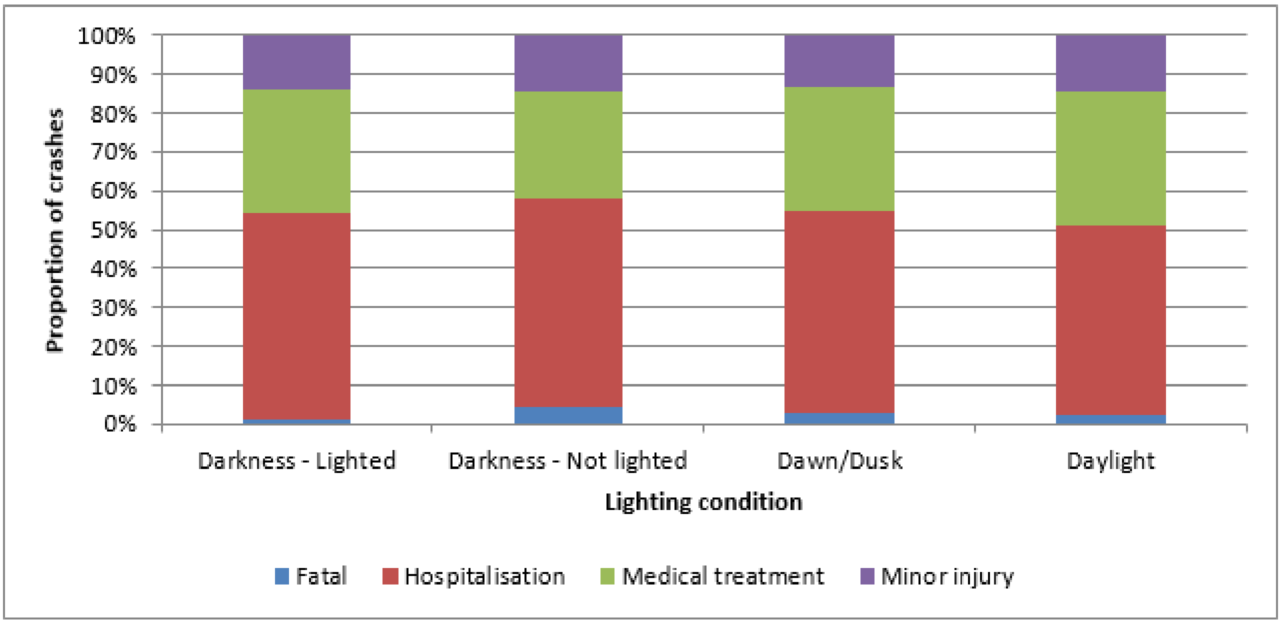


Figure 3.79: Out-of-control injury crashes by lighting condition and severity (2007-11)

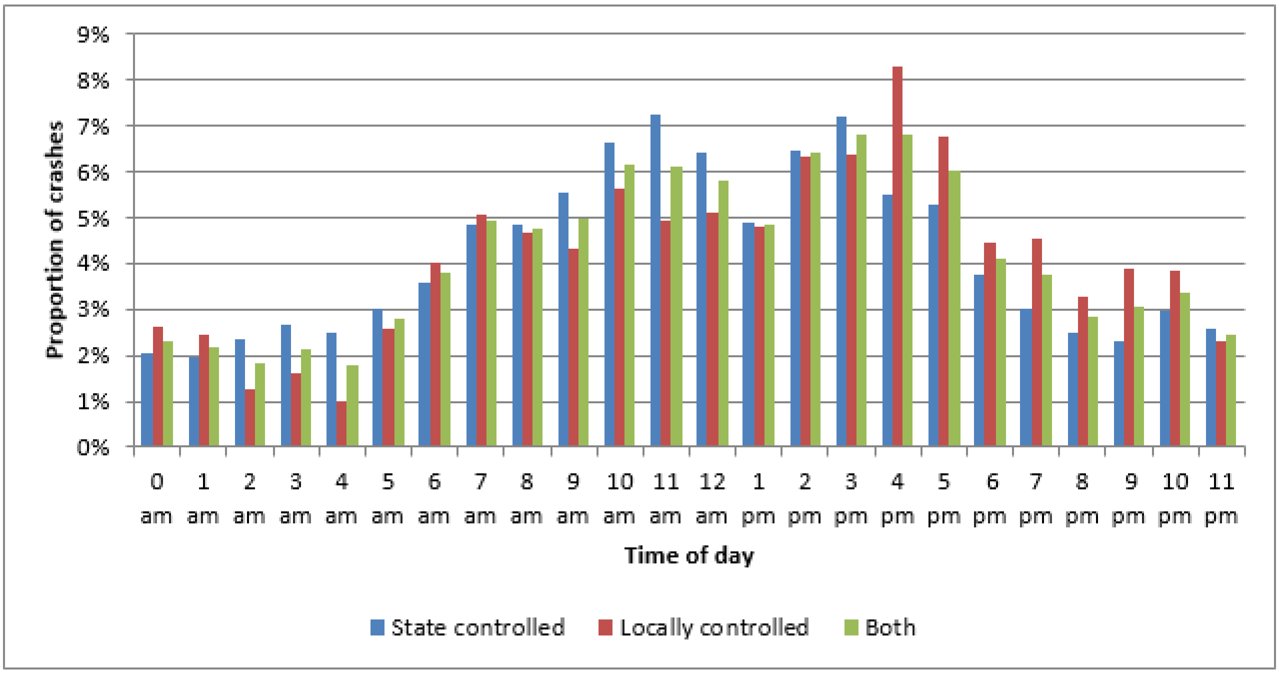


3.5.8 Out-of-control Injury Crashes by Time of Day

Figure 3.80 shows that the peaks for OOC injury crashes occurred at 3pm and 4pm. There is no clear morning peak, however incidences of these crashes do rise, as the time approaches 7am and again at 10am. The crash proportions on both state and locally controlled roads appear to drop off after 4pm.

The proportions of crashes during the morning peak (7-9 am) and evening peak (3-6 pm) are 10% and 20% respectively. These proportions are lower compared to all injury crashes. On the other hand, the proportion of OOC injury crashes (13%) from mid-night to 6 am is higher than that for all injury crashes (8%).

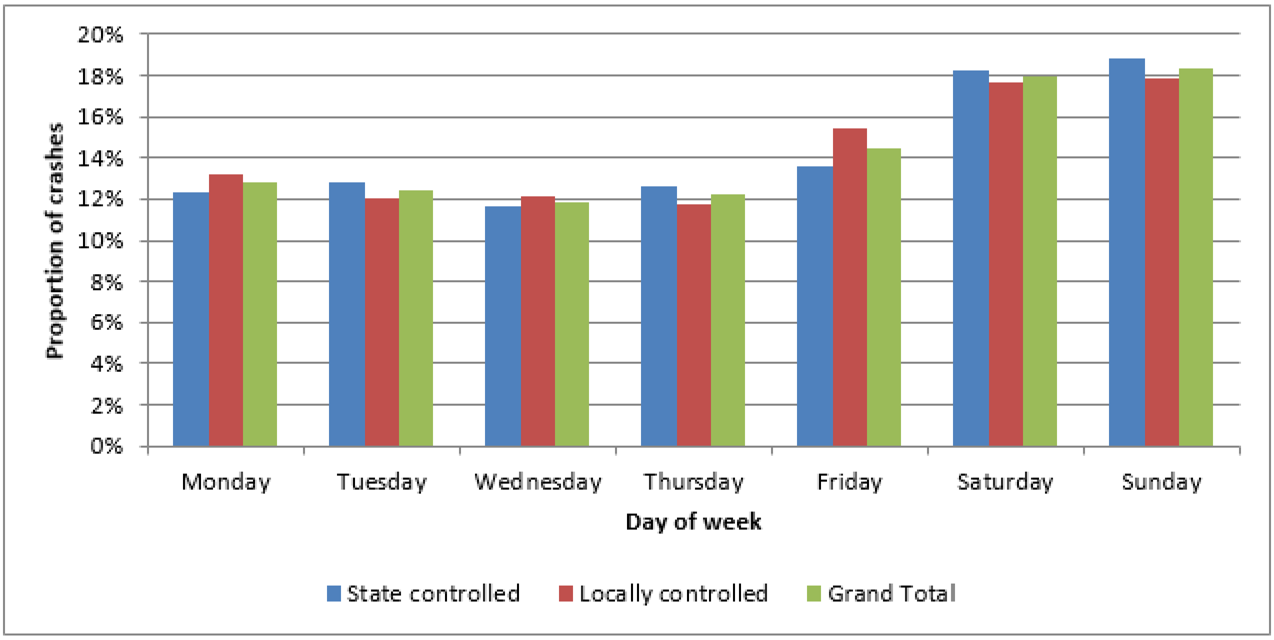
Figure 3.80: Out-of-control injury crashes by time of day (2007-11)



3.5.9 *Out-of-control Injury Crashes by Day of week*

Figure 3.81 shows the weekly pattern of OOC injury crashes. The largest proportion of OOC injury crashes occurred during the weekends, which is different from all injury crashes (Figure 3.25). The proportion of OOC injury crashes on weekends (36%) is significantly higher than that of all injury crashes (25%).

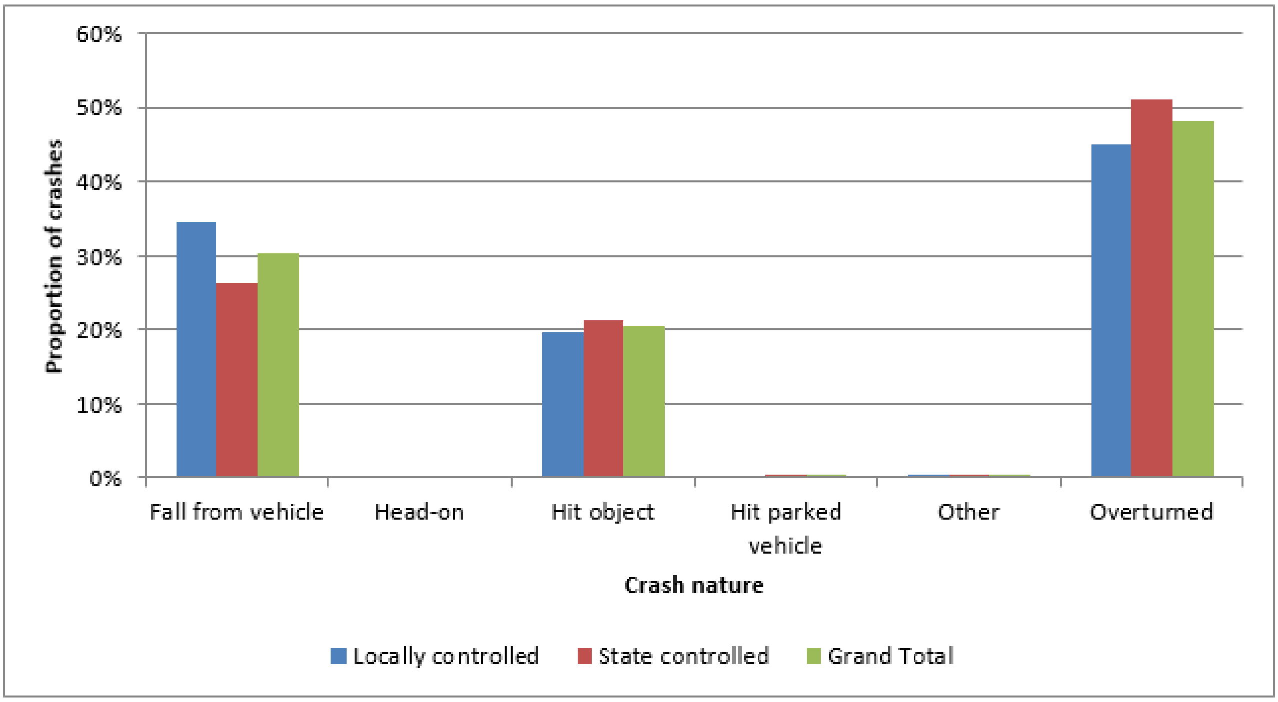
Figure 3.81: Out-of-control injury crashes by day of the week (2007-11)



3.5.10 Out-of-control Injury Crashes by Crash Nature

Figure 3.82 shows the breakdown of OOC injury crashes by crash type. The main crash types are an overturned vehicle (48%), fall from vehicle (30%) and hit object (21%).

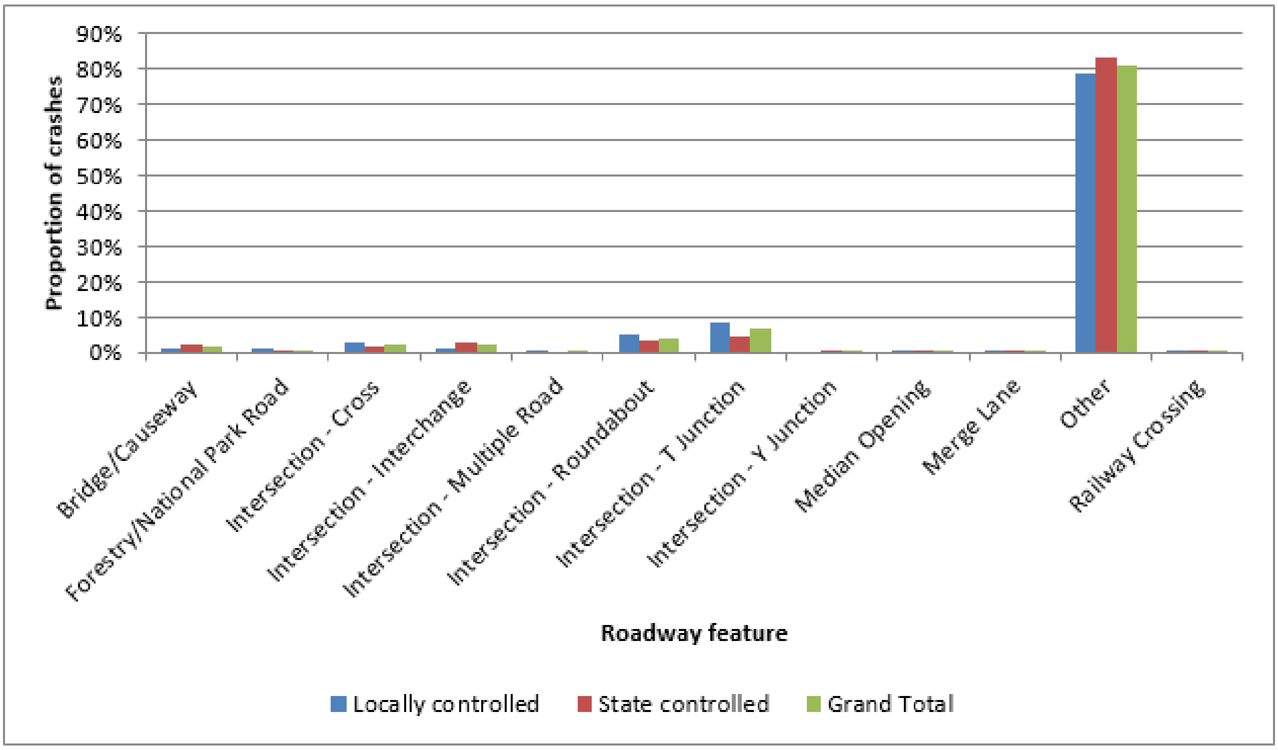
Figure 3.82: Out-of-control injury crashes by crash nature (2007-11)



3.5.11 Out-of-control Injury Crashes by Roadway Features

Figure 3.83 shows the proportion of OOC injury crashes by road feature. Most of the OOC injury crashes occurred at mid-block sections (81%). Most of the OOC injury crashes at intersections occurred at 3-leg intersections and roundabouts.

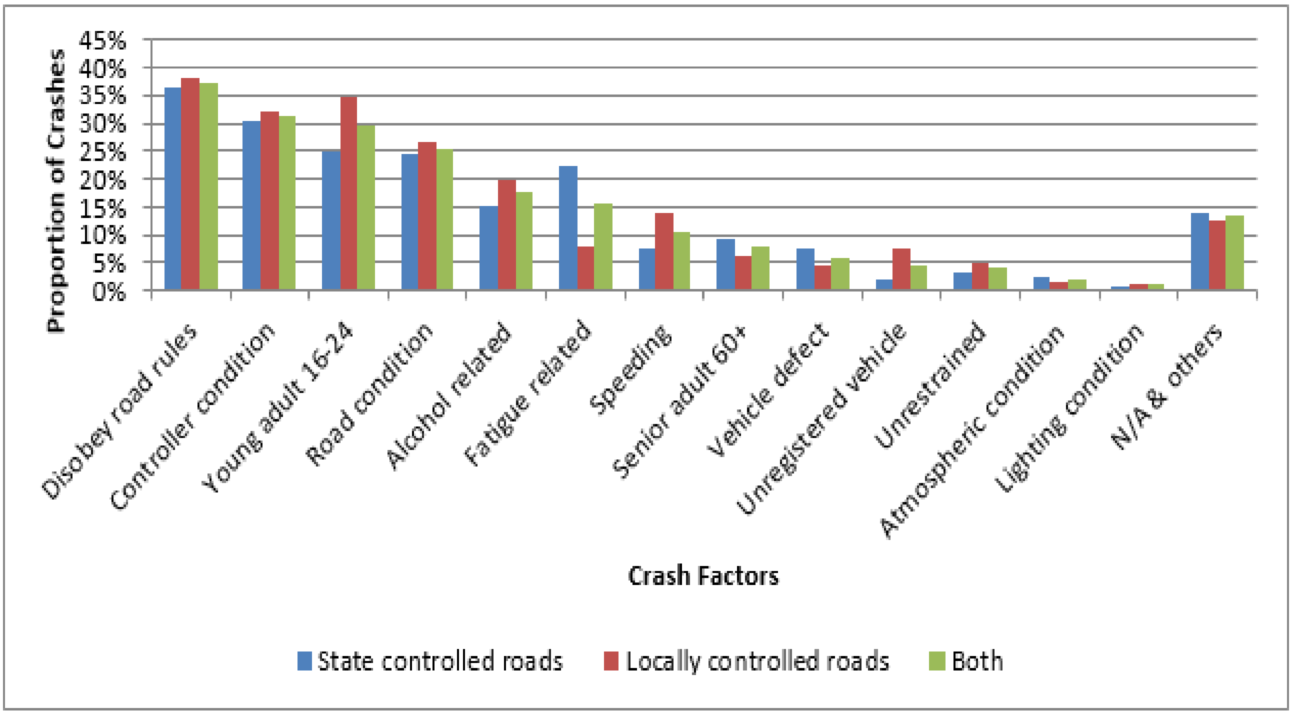
Figure 3.83: Out-of-control injury crashes by roadway feature (2007-11)



3.5.12 *Out-of-control Injury Crashes by Crash Factors*

The major recorded crash causing factors for OOC injury crashes included disobeying the road rules (37%), controller condition (31%), young adult drivers between 16 and 24 (30%) and road condition (26%) (Figure 3.84).

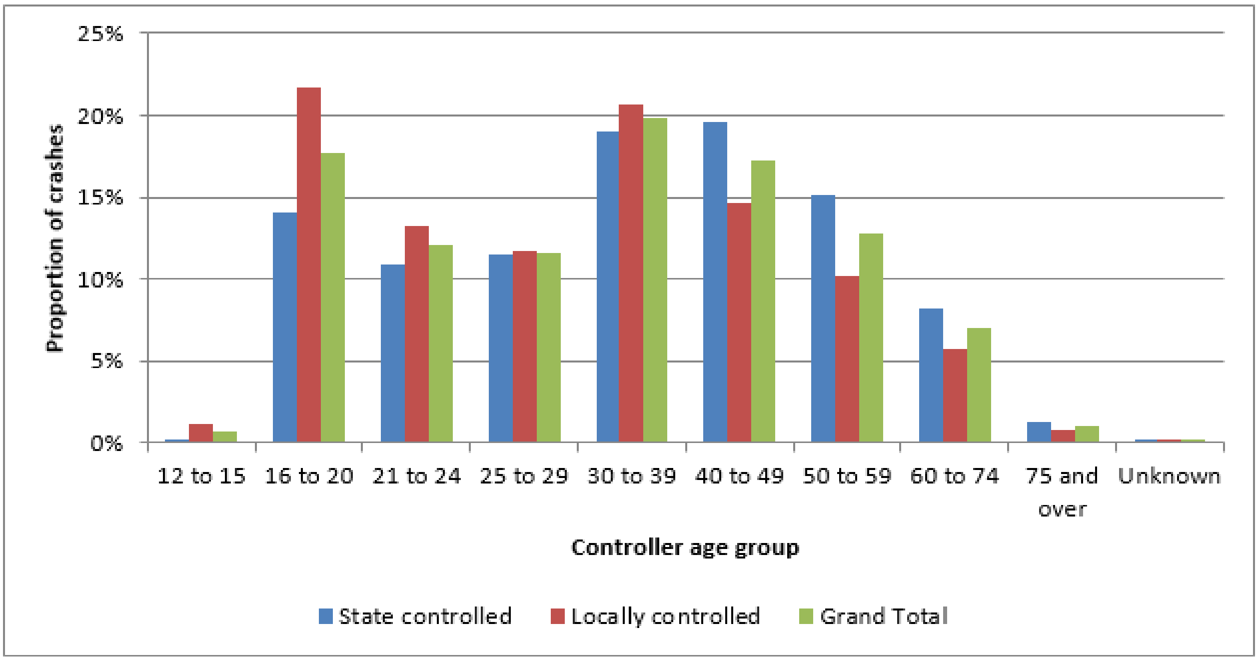
Figure 3.84: Out-of-control injury crashes by crash factor (2007-11)



3.5.13 *Out-of-control Injury Crashes by Primary Vehicle Controller Age*

Figure 3.85 shows the age groups of the primary vehicle controller involved in OOC injury crashes. Young controllers 16-24 years old accounted for 30% of OOC injury crashes, followed by the 30-39 years age group (19%), the 25-29 years (13%) and 40-49 years age group (13%).

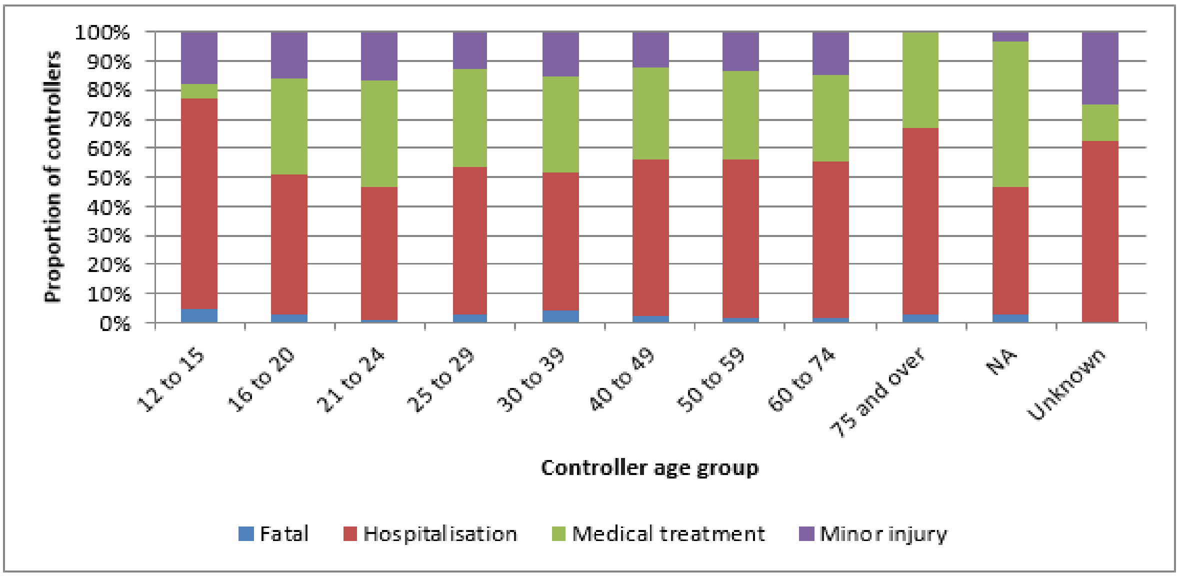
Figure 3.85: Out-of-control injury crashes by primary vehicle controller age (2007-11)



The risk for controllers (less than 40 years) are higher on locally controlled roads while controllers 40 years and over have higher risk on state-controlled roads (Figure 3.85).

Very young controllers 5-12 years and older controllers 75 years and over recorded the highest proportion of FSI crashes, i.e. the young and the elderly have higher severity outcomes for OCC crashes (Figure 3.86).

Figure 3.86: Severity of out-of-control crashes by primary vehicle controller age (2007-11)



3.5.14 Out-of-control Injury Crashes by Primary Vehicle Controller Gender

Figure 3.87 shows that male controllers of the primary vehicle accounted for about 78% of the OOC injury crashes. This proportion is higher than that for all injury crashes. The proportion of male and female controllers were similar between state-controlled and locally controlled roads. The risk of an OOC fatal or FSI crash was higher for male controllers (Figure 3.88).

Figure 3.87: Out-of-control injury crash controllers by gender (2007-11)

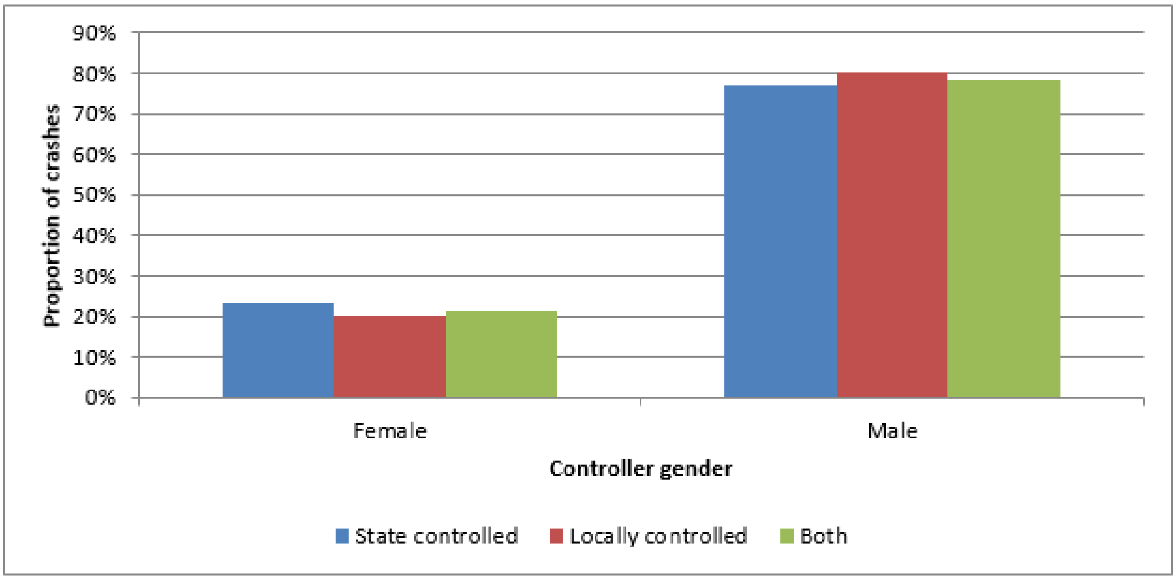
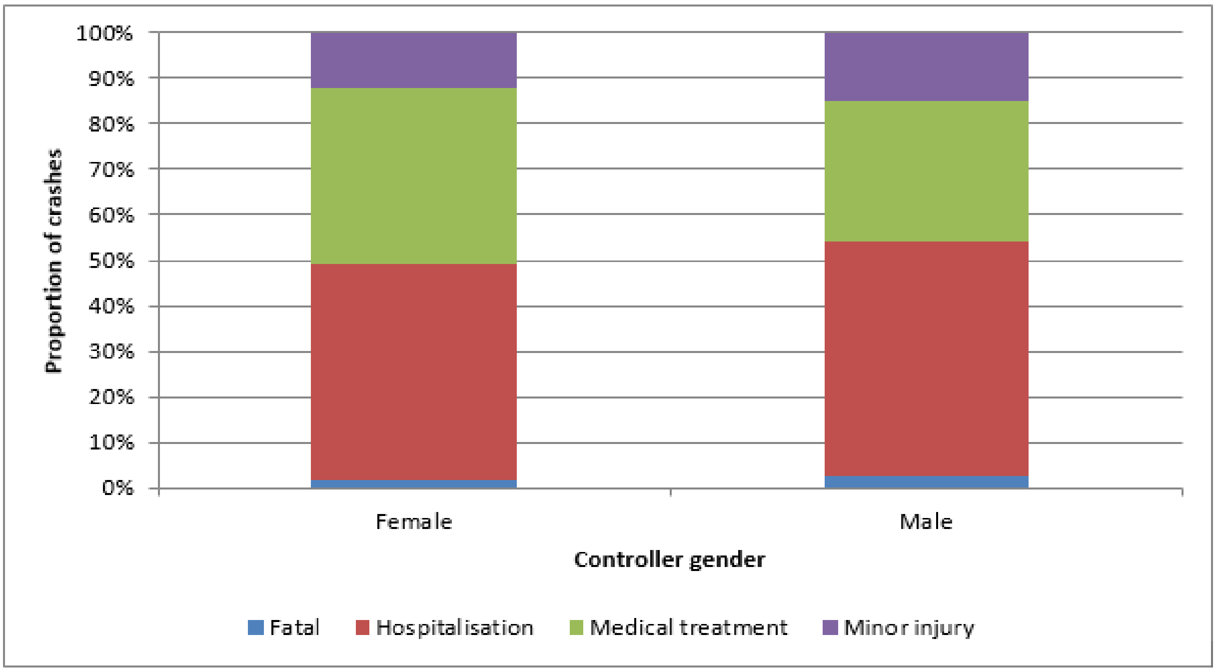


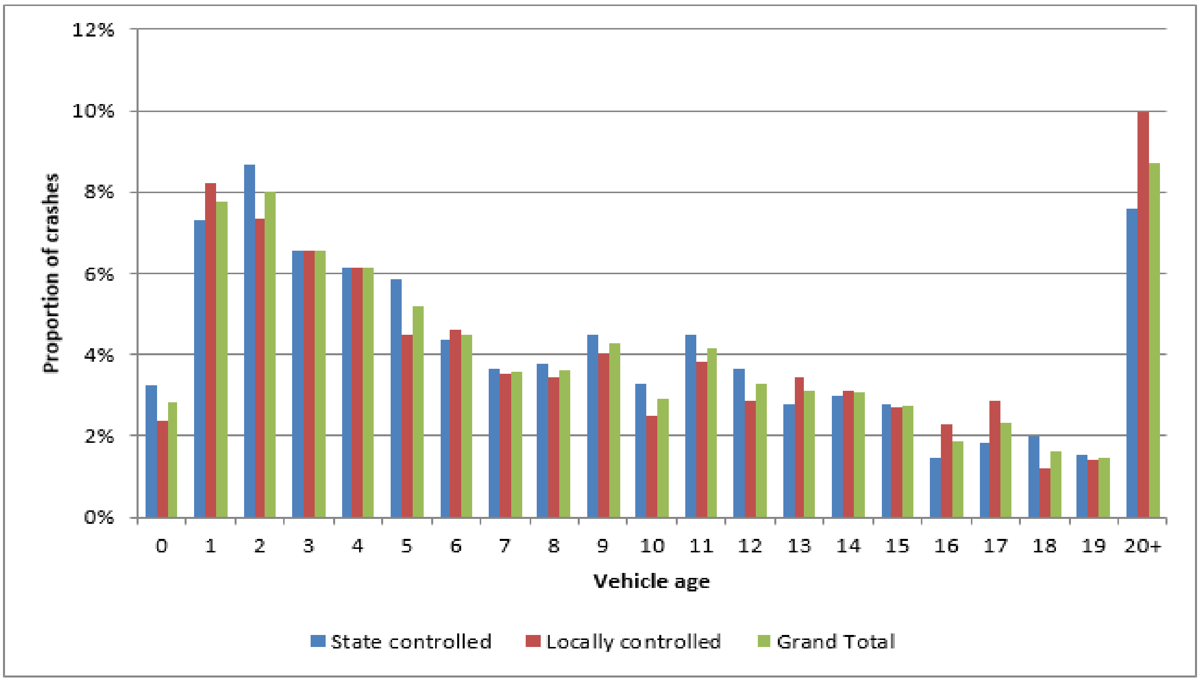
Figure 3.88: Out-of-control injury crash controllers by gender and severity (2007-11)



3.5.15 Out-of-control Injury Crashes by Primary Vehicle Age

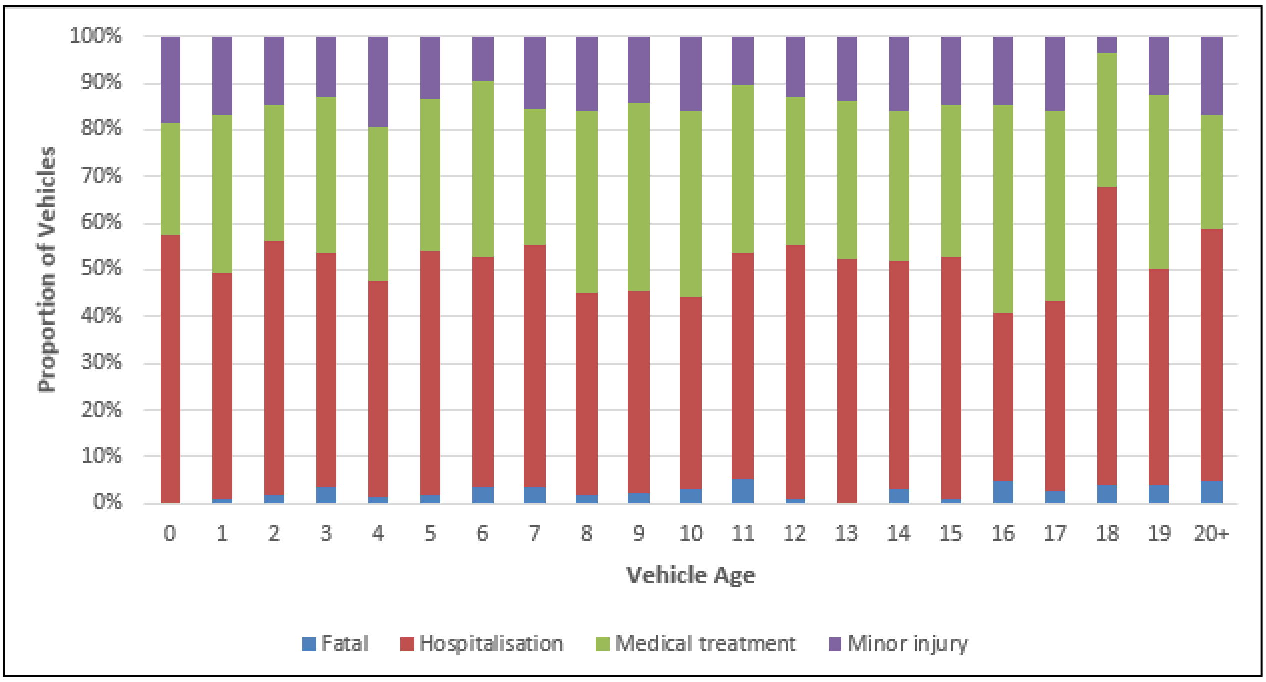
Figure 3.89 shows the age of the primary vehicles involved in OOC injury crashes. The two and three year old vehicles recorded highest proportion of OOC injury crashes. On the whole after three years, there appears to be a decrease in OOC injury crashes with the age of the primary vehicle.

Figure 3.89: Out-of-control injury crashes by primary vehicle age (2007-11)



There is no discernable pattern between vehicle age and severity of OOC crashes (Figure 3.90). On average vehicles aged 18 years and over recorded high proportion of FSI crashes. The greatest proportion of fatalities occurred with vehicles aged 11 years at 5%.

Figure 3.90: Severity of out-of-control injury crashes by primary vehicle age (2007-11)



3.5.16 Out-of-control Injury Crashes by Primary Vehicle Type

Figure 3.91 shows the proportion of primary vehicle types involved in OOC injury crashes. Compared to other crash types, motorcycles/mopeds are over-represented in OOC injury crashes.

Special purpose vehicles recorded the highest proportion of FSI out-of-control crashes (Figure 3.92)

Figure 3.91: Out-of-control injury crashes by primary vehicle type (2007-11)

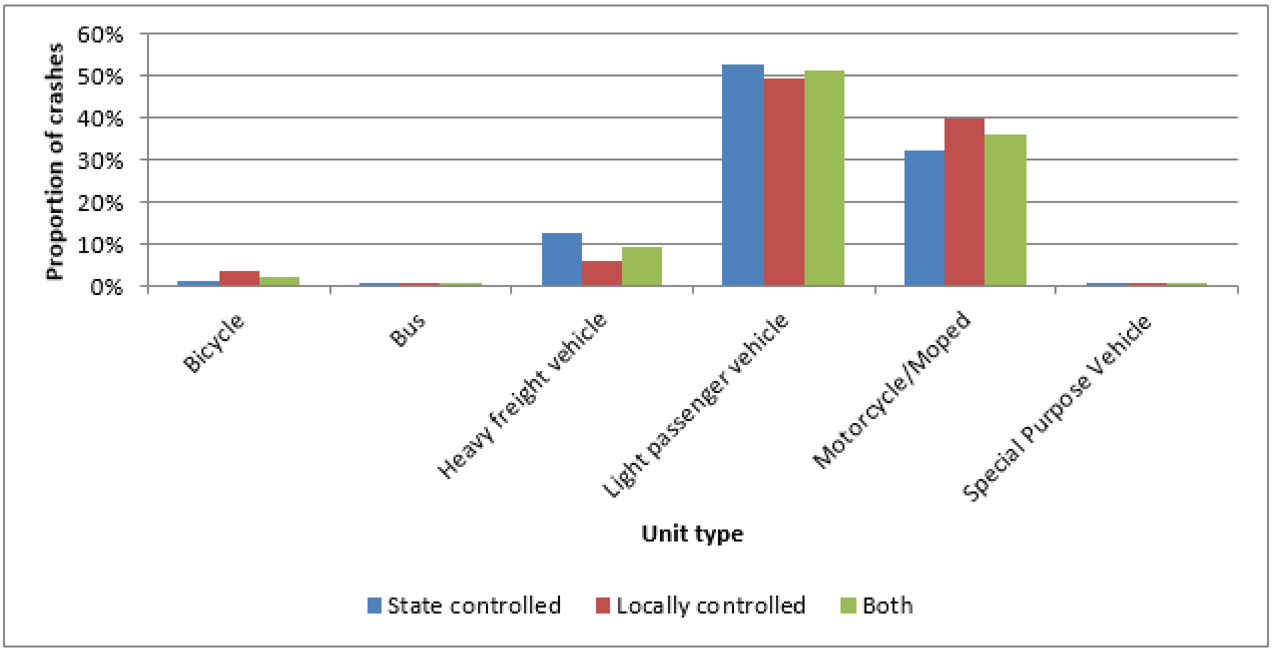
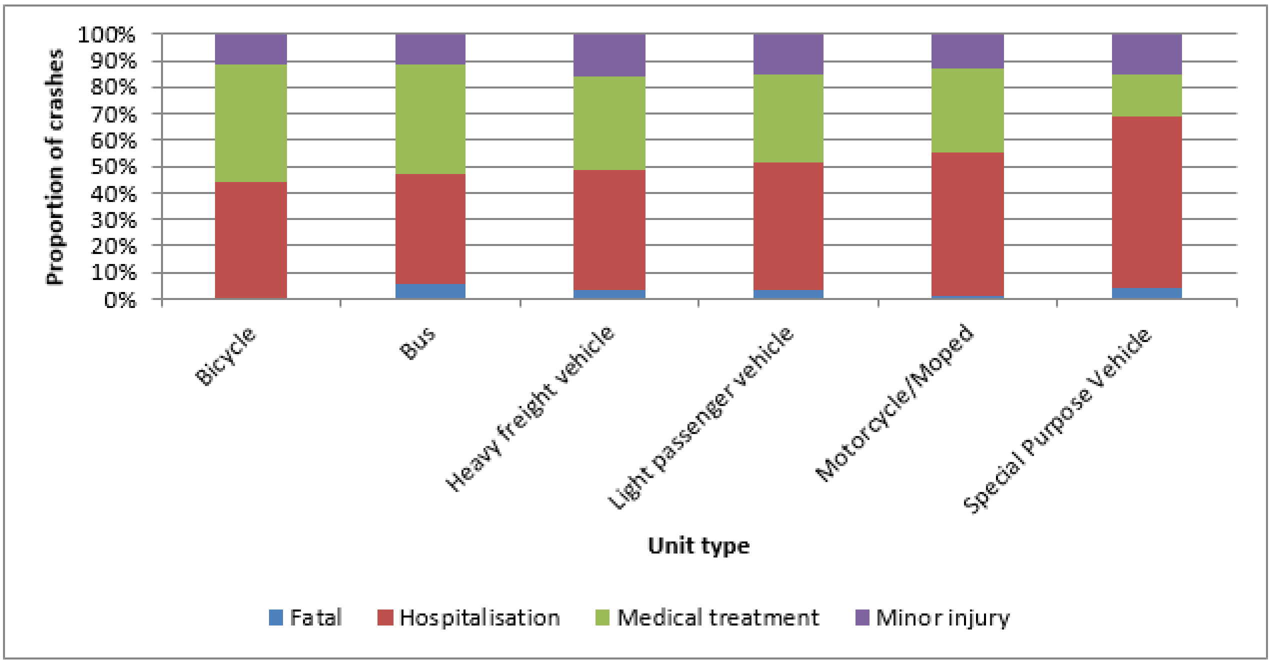


Figure 3.92: Severity of out-of-control injury crashes by vehicle type (2007-11)



3.5.17 High Out-of-control High Crash Risk Sections – State-co

State Roads with high number of out-of-control crashes

Figure 3.93 shows the top 10 road sections with the highest numbers of OCC injury crashes. Road section 12A recorded the highest number of OOC injury crashes, but 10A has the highest risk in terms of the proportion of FSI crashes.

Table 3.12 shows the top 10 road sections with the highest OCC crash cost. The top 50 state-controlled road sections with the highest OOC crash cost are provided in Appendix C, Table C1.

Figure 3.93: Out-of-control injury crashes by road and severity – road sections with highest number of crashes (2007-11)

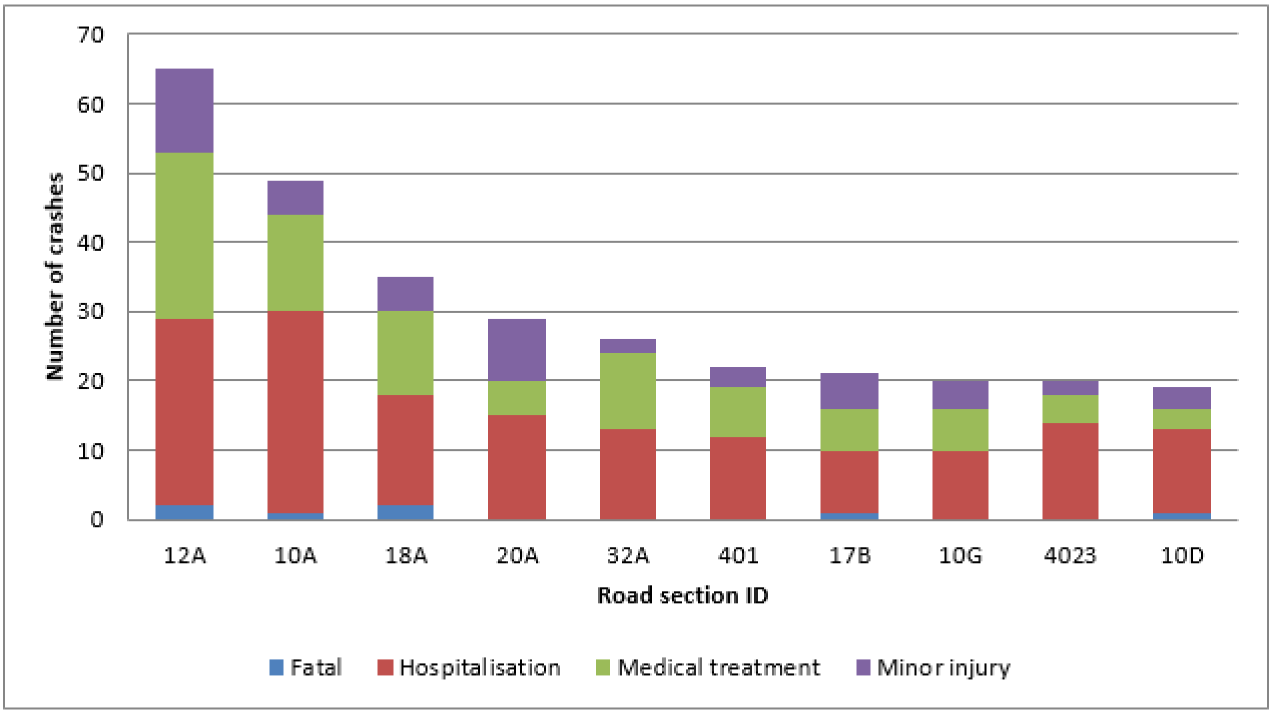


Table 3.12: Top 10 road sections with the highest number of out-of-control injury crashes (2007-11)

Road Sections	Fatal – OOC crashes	Hospitalisation – OOC crashes	Medical treatment – OOC crashes	Minor injury – OOC crashes	Total – OOC injury crashes	Annual average OOC crash cost
90D	4	4	5	1	14	$6,925,061
12A	2	27	24	12	65	$5,838,307
18A	2	16	12	5	35	$4,723,934
10A	1	29	14	5	49	$4,088,187
10D	1	12	3	3	19	$2,594,226
17B	1	9	6	5	21	$2,454,091
10F	1	10	3	3	17	$2,447,922
495	1	8	6	0	15	$2,342,995
10C	1	7	3	1	12	$2,213,288
N239	1	5	6	0	12	$2,123,539

Out-of-control collective risk for state-controlled roads

The top 10 state-controlled road sections with highest collective risk for OOC crashes based on crash cost per km are shown in Table 3.13. The top 50 high collective OOC crash risk state-controlled road sections are provided in Appendix C, Table C2.

Table 3.13: Top 10 state-controlled roads with high out-of-control crash cost per km, 2007-11 (collective risk)

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total OOC injury crashes	Total OOC FSI crashes	Annual average OOC injury crashes per km	Annual average OOC injury crash cost per km	Annual average OOC injury crashes per 100M veh-km	Annual average OOC injury crash cost per 1000 veh-km
208	4.66	15107	3	2	0.129	$369,962	2.34	$68.00
1122	6.81	22149	4	2	0.117	$256,300	1.45	$32.00
2029	7.55	NA	4	2	0.106	$229,353	NA	NA
U21	0.84	31288	2	1	0.476	$112,540	4.17	$10.00
2020	18.44	1502	8	6	0.087	$110,521	15.82	$202.00
185	19.29	9957	8	6	0.083	$105,673	2.28	$30.00
12A	79.32	75359	65	29	0.164	$73,605	0.60	$2.00
U93	1.19	5363	2	1	0.336	$67,850	17.17	$34.00
U27	6.45	NA	8	4	0.248	$56,487	NA	NA
U98	7.2	31282	6	5	0.167	$53,770	1.46	$4.00

Out-of-control individual risk for state-controlled roads

The top 10 state-controlled roads with the highest individual OOC crash risk based on crash cost per VKT are shown in Table 3.14. The top 50 high individual OOC crash risk roads are provided in Appendix C, Table C3.

Table 3.14: Top 10 state-controlled roads with high out-of-control crash cost per $1000 veh-km (individual risk), 2007-11

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total OOC injury crashes	Total OOC FSI crashes	Annual average OOC injury crashes per km	Annual average OOC injury crash cost per km	Annual average OOC injury crashes per 100M veh-km	Annual average OOC injury crash cost per 1000 veh-km
7003	184.83	34	1	1	0.001	$8,816	8.77	$714.00
90D	219.53	139	14	8	0.013	$31,545	25.18	$622.00
3251	45.61	174	2	2	0.009	$37,330	13.83	$588.00
7708	169.08	71	2	1	0.002	$9,764	9.18	$378.00
3306	45.03	309	2	2	0.009	$37,811	7.87	$334.00
405	46.65	692	5	5	0.021	$74,565	8.49	$296.00
4023	27.11	429	20	14	0.148	$41,491	94.16	$264.00
3341	4.67	178	1	1	0.043	$15,664	66.10	$242.00
232	99.18	207	3	3	0.006	$17,905	8.00	$236.00
2020	18.44	1502	8	6	0.087	$110,521	15.82	$202.00

3.6 Impact of AADT on Crashes

Relationship between injury crashes and AADT are shown in Figure 4.1 to Figure 4.6. The proportion of injury crashes covered considering AADT cut-off value of 1000, 2000 and 3500 as selection criteria are shown in Table 3.15. The cut-off AADT value has a major impact on head-on crashes than the other crash types. There are more run-off-road and out-of-control crashes at low traffic volume compared to head-on crashes. For 2000 AADT cut-off site selection criteria, the results indicate that:

- 83% of head-on injury crashes are covered (i.e. 17% of head-on injury crashes occur on roads with less than 2000 AADT)
- 72% of run-off-road crashes are covered (i.e. 28% of run-off-road injury crashes occurred on roads with less than 2000 AADT)
- 62% of out-control crashes are covered (i.e. 38% of out-of-control injury crashes occur on roads with less than 2000 AADT)

Table 3.15: Proportion of injury crashes covered at various AADT cut-off selection criteria

Crash type	Proportion of crashes covered for AADT >= 1000	Proportion of crashes covered for AADT >= 2000	Proportion of crashes covered for AADT >= 3500
Head-on injury crashes	90% (91%)	83% (83%)	67% (67%)
Run-off-road injury crashes	81% (79%)	72% (70%)	60% (57%)
Out-of-control injury crashes	72% (70%)	62% (60%)	51% (48%)

Note: Proportion of FSI crashes in bracket

Figure 3.94: All injury head-on crashes and AADT relationship (2007-11)

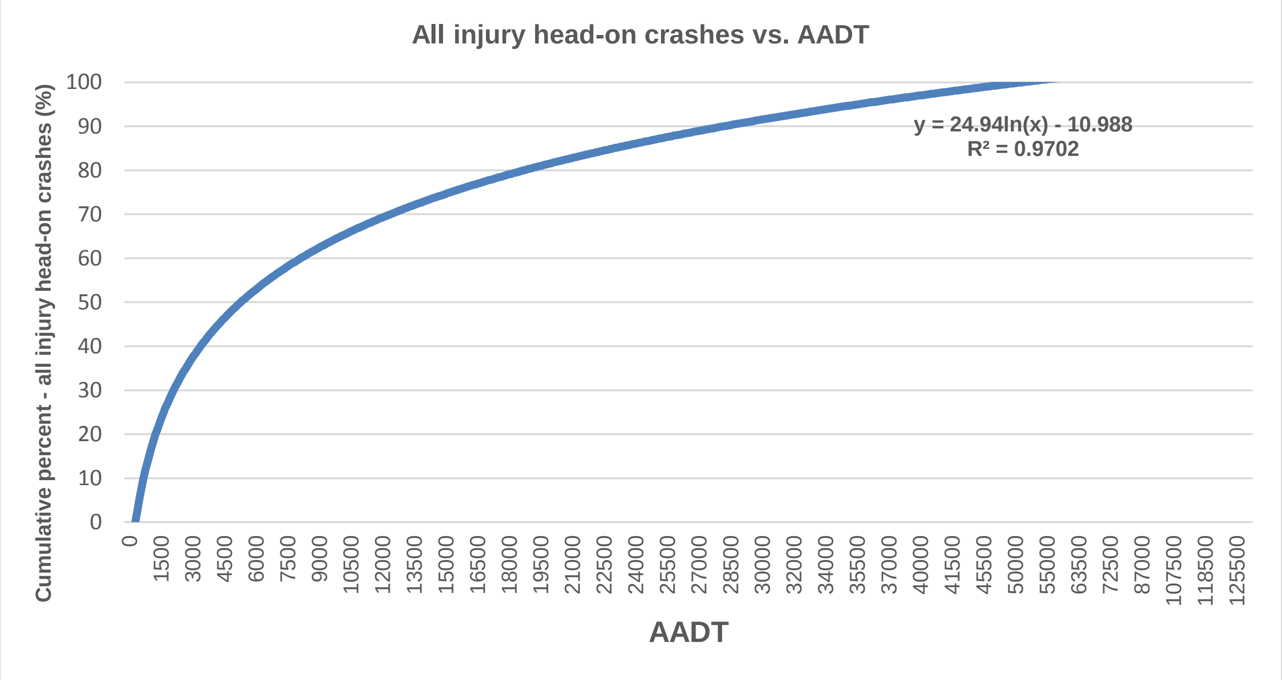


Figure 3.95: Head-on FSI crashes and AADT relationship (2007-11)

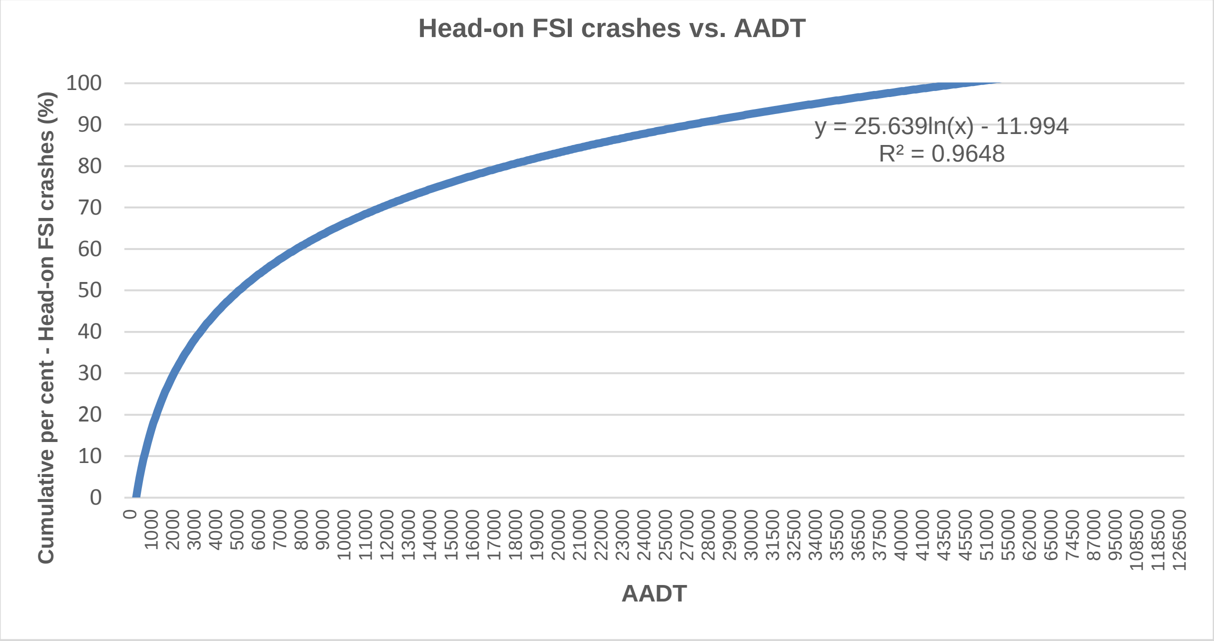


Figure 3.96: All injury run-off-road crashes and AADT relationship (2007-11)

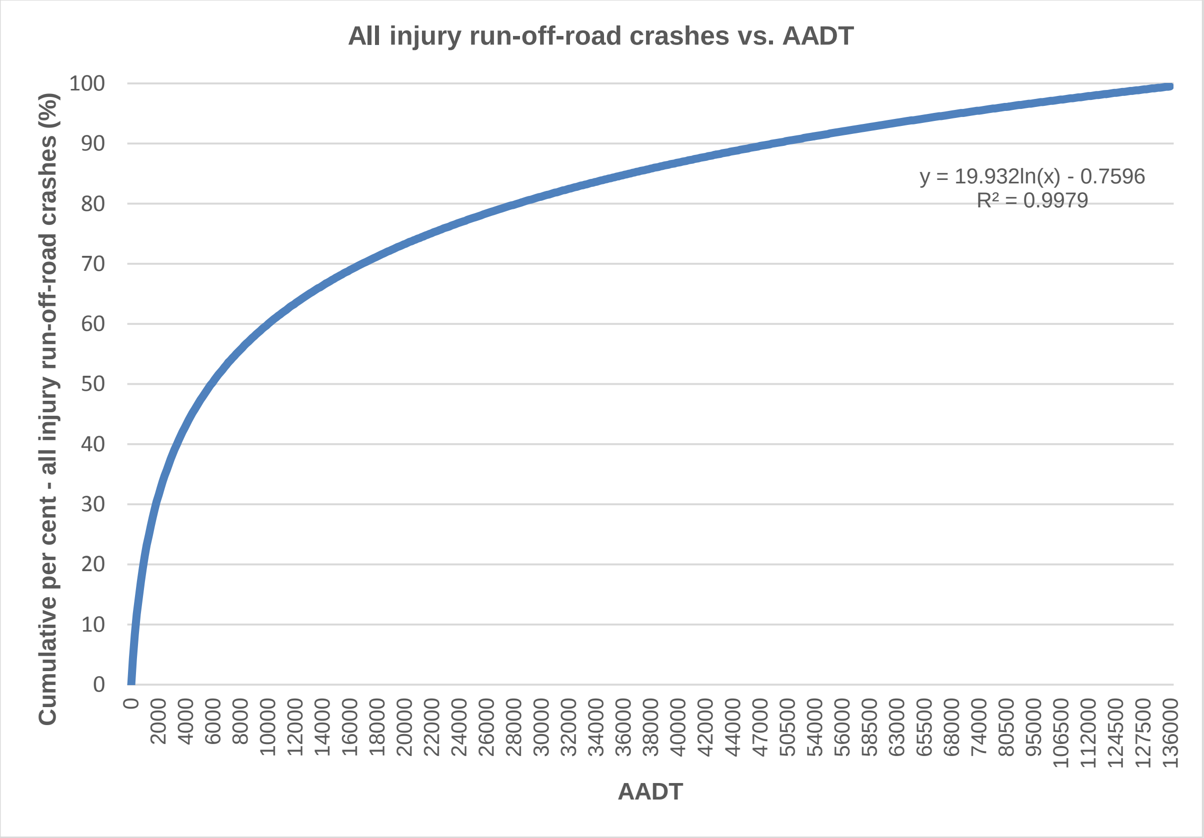


Figure 3.97: Run-off-road FSI crashes and AADT relationship (2007-11)

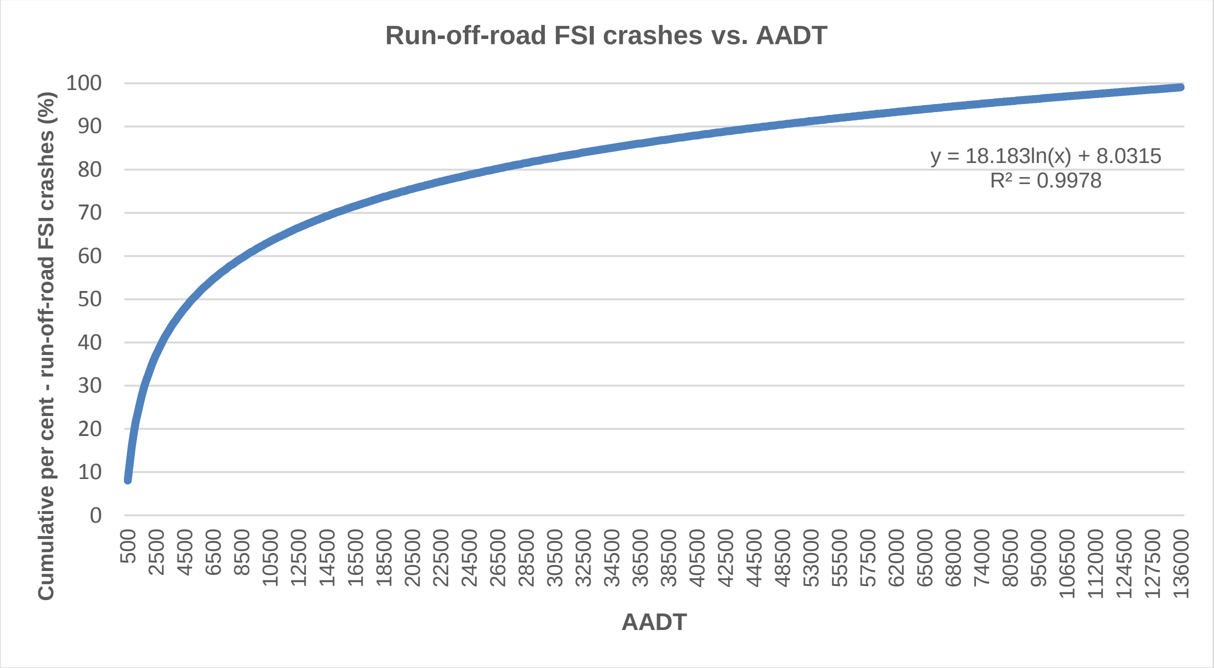


Figure 3.98: All injury out-of-control crashes and AADT relationship (2007-11)

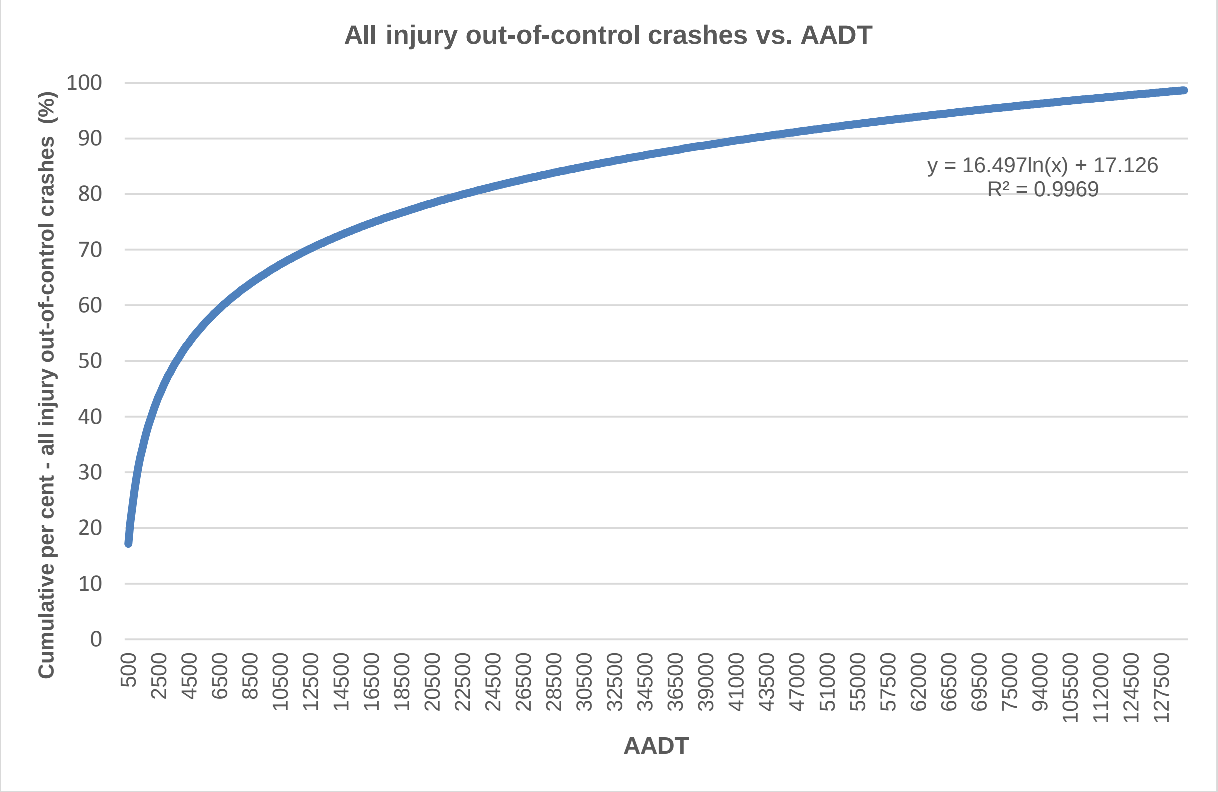
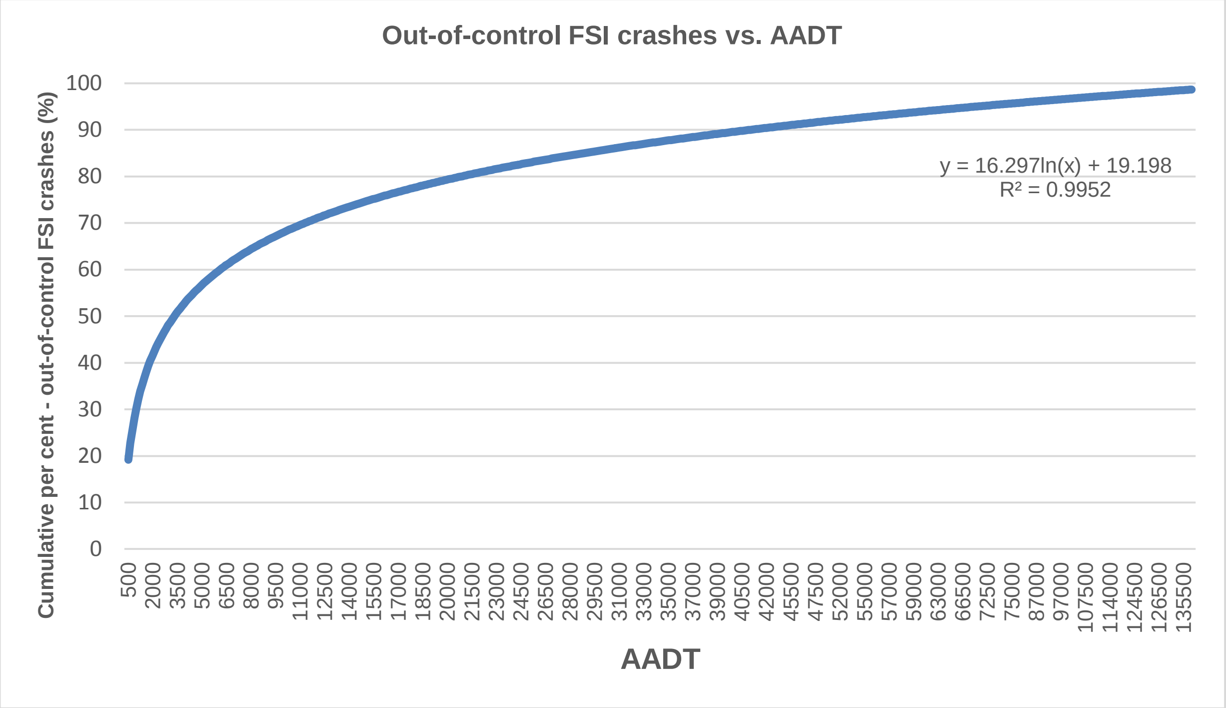


Figure 3.99: Out-of-control FSI crashes and AADT relationship (2007-11)



3.7 Summary Crash Analysis Findings

Over the five year period (2007-11), there were a total of 69 533 injury crashes recorded on Queensland roads of which 40% were FSI crashes. Out of the 69 533 injury crashes 4% were head-on crashes, 21% were ROR crashes and 5% were OOC crashes.

3.7.1 Head-on Injury Crashes

The analysis of head-on crashes revealed the following:

- Fifty-two per cent of head-on injury crashes occurred on state-controlled roads
- Head-on crashes represent 6% of FSI on QLD roads, and 7% of FSI on state-controlled roads
- Head-on crashes were more severe compared to all crash types (61% of head-on injury crashes were FSI crashes compared to 40% for all injury crashes)
- The risk of a fatal head-on crash was higher on state-controlled roads (16% of head-on injury crashes on state-controlled roads were fatal compared to 5% on locally controlled roads)
- Majority of head-on injury crashes on state-controlled roads occurred on high speed zones 80 km/h or more)
- The FSI proportion of head-on injury crashes increased with increasing posted speed limit
- The risk of a head-on injury crash on horizontal curves was higher than for all injury crashes – 56% of head-on injury crashes occurred on curves compared to 23% for all injury crashes
- Vertical grade was found to have effect on the likelihood of head-on crashes, but had no effect on the severity of the crash (42% of head-on injury crashes occurred on a grade, dip or crest)

- There were more head-on crashes on wet road surface (26%) compared to all injury crashes (16%), but the risk of a severe head-on crash was slightly lower on wet surfaces than dry ones, probably due to a reduction in speed during wet weather.
- Lighting condition had no significant impact on head-on crashes, however, un-lighted roads recorded the highest proportion of FSI head-on crashes during darkness time.
- There were more head-on injury crashes (30%) during the weekends compared to that of all injury crashes (25%)
- Most of the head-on injury crashes at intersections occurred at 3-leg intersections, most of which are unsignalised.
- The top five contributing factors recorded for head-on injury crashes were disobeying the road rules (80%), young adults, 17-24 age old (39%), senior adults, 60+ years (24%), road condition (22%) and controller condition (19%).
- Young controllers (17-24 years old) comprised 30% of the primary vehicle controllers involved in head-on injury crashes.
- As primary vehicle controller, male drivers accounted for about 70% of the head-on injury crashes (i.e. higher risk of a head-on crash for male controllers).
- The risk of a fatal head-on crash was higher for heavy vehicles compared to other vehicle types, while motorcycles/mopeds had the highest proportion of FSI head-on crashes.

3.7.2 Run-off-road Injury Crashes

The findings from the analysis of run-off-road crashes include the following:

- About 48% of ROR injury crashes occurred on state-controlled roads
- ROR crashes represent 27% of FSI on QLD roads, but 29% of FSI on state-controlled roads
- The risk of FSI crashes was higher for ROR compared to all injury crashes (51% of ROR injury crashes were FSI crashes compared to 40% for all injury crashes)
- The risk of a fatal ROR crash is marginally higher on state-controlled roads (4% of ROR injury crashes on state-controlled roads were fatal compared to 3% on locally controlled roads)
- Majority of ROR injury crashes on state-controlled roads occurred on high speed zones 80 km/h or more)
- The proportion of the fatal ROR crashes increased with the posted speed limits
- The risk of a ROR injury crash on horizontal curves was higher than for all injury crashes – 44% of ROR injury crashes occurred on curves compared to 23% for all injury crashes
- Vertical grade had impact on the likelihood of ROR crash occurrence , but had no effect on the severity of the crash (31% of ROR injury crashes occurred on a grade, dip or crest)
- There were more ROR crashes on wet road surface (22%) compared to all injury crashes (16%), but the risk of a severe ROR crash is lower on wet surfaces than dry ones.
- The risk of a ROR injury crash during poor lighting condition (i.e. dark and dusk/dawn) was higher (46%) than for all injury crashes (30%).
- There were comparatively more ROR injury crashes during the night compared to all injury crashes.
- The peak period for ROR injury crashes occurred on the weekends.
- Most of the ROR injury crashes (72%) resulted in a collision with roadside object and a further 17% resulted in an overturned vehicle.

- The top five contributing factors recorded for ROR injury crashes were disobeying the road rules (49%), young adults 17-24 age old (37%), controller condition (33%), alcohol related (25%) and road condition (19%).
- Fatigued drivers were found to be a contributing factor in 27% of the ROR crashes on state-controlled roads.
- Young controllers (17-24 years old) comprised 36% of the primary vehicle controllers involved in ROR injury crashes.
- Male controllers were involved in two-thirds of ROR injury crashes and also have a higher risk of being involved in a severe ROR crash.
- There is an overall decreasing trend in the proportion of ROR crashes with the age of the primary vehicle, especially after 12 years.
- Motorcycles/mopeds (69%) and bicycle riders (59%) had the highest risk of FSI resulting from a ROR crash.

3.7.3 Out-of-Control Injury Crashes

The analysis of OOC crashes revealed the following:

- There has been a 55% reduction in fatal out-of-control crashes between 2007 and 2011, but a 10% increase in out-of-control FSI crashes.
- 52% of OOC injury crashes were FSI crashes, which is higher than the 40% for all injury crash types
- The FSI proportion of OOC crashes generally increased with increasing posted speed limit
- The risk of a OOC injury crash on horizontal curves was higher than for all injury crashes – 47% of OOC injury crashes occurred on curves compared to 23% for all injury crashes
- The risk of a OOC injury crash on vertical was higher than for all injury crashes – 36% of OOC injury crashes occurred on a grade/dip/crest compared to 25% for all injury crashes
- There are more OOC injury crashes on unsealed roads (13%) compared to all injury crashes (3%).
- More than a third (35%) of OOC injury crashes occurred in poor lighting conditions (darkness/dawn/dusk)
- The top five contributing factors recorded for OOC injury crashes were disobeying the road rules (37%), controller condition (31%), young adults 17-24 age old (30%), road condition (25%) and alcohol related (17%).
- Fatigued drivers were found to be a contributing factor in 22% of the OOC crashes on state-controlled roads.
- Young controllers (17-24 years old) comprised 30% of the primary vehicle controllers involved in OOC injury crashes.
- Male controllers were involved in 78% of OOC injury crashes and also have a higher risk of being involved in a serious OOC crash.
- Motorcycles/mopeds were over-represented in OOC injury crashes.
- Special purpose vehicles had the highest FSI proportion for OOC crashes (69%) followed by motorcycles (55%).

3.7.4 Summary Statistics

A summary of the key crash characteristics and performance measures by crash type are provided in Table 3.16.

Table 3.16: Key crash characteristics by crash type

Parameter	Head-on injury crashes	Run-off-road injury crashes	Out-of-control injury crashes	All QLD injury crashes
Total injury crashes	2,556 (4%)	14,821 (21%)	3,265 (5%)	69,533 (100%)
Fatal and serious injury crashes (FSI)	1,548 (6%)	7,567 (27%)	1726 (6%)	27,877 (100%)
Proportion of fatal crashes by crash type	11%	3%	3%	2%
Proportion of FSI by crash type	61%	48%	52%	40%
Horizontal curves	56%	44%	47%	23%
On all high speed road sections (>=80 km/h)	47%	47%	55%	27%
On high speed state roads (>=80 km/h)	69%	71%	72%	45%
Vertical grade, dip or crest	42%	31%	36%	25%
Wet road surface condition	27%	22%	16%	16%
Unsealed condition			13%	3%
Dawn/Dusk/Darkness light conditions	29%	46%	35%	30%
Peak periods (7-9 am, 4-6 pm)	36%	27%	32%	36%
High risk vehicle by FSI	Motorcycles	Motorcycles	Special purpose vehicles	Motorcycles
Week day crashes	70%	64%	64%	75%
Young adults as contributing factor	39%	37%	30%	37%
Disobey road rules as contributing factor	80%	49%	37%	67%
Road condition	22%	19%	25%	10%
Fatigue as contributing factor on state roads	9%	27%	22%	9%
Male Controllers	70%	67%	78%	62%
Age group with highest involvement as primary vehicle controller	16-24 years (30%)	16-24 years (36%)	16-24 years (30%)	16-24 years (29%)

4 ENGINEERING TREATMENTS

4.1 Head on Crash Countermeasures

The aim of head-on countermeasures is to separate opposing traffic. The most cost-effective head-on specific treatments include road duplication, two plus one (2+1) lane, centreline treatments, overtaking lanes and speed reduction.

4.1.1 Road-Duplication and Physical Barriers

The most effective means to reduce the head-on crashes is to provide physical separation of opposing traffic. This may involve a major road upgrade or duplication to construct a central median, to provide an area for errant vehicles to recover in the event of leaving the roadway.

Median safety barriers are also used to prevent errant vehicles from entering opposing lanes of traffic. These include concrete barriers, w-beam metal barriers and recently wire rope barriers. The literature review indicated the wire rope or flexible barrier systems to have significant success in the reduction of head-on crashes and the severity of crashes.

It has been suggested that the flexible barrier system has higher ongoing maintenance cost compared to other systems due to nuisance hits, etc., however due to the high (70-90%) crash reduction achieved by the use of this treatment it is recommended for sites that have a high head-on crash risk.

4.1.2 Two plus one (2+1) Lane (with Wire Rope) Treatment

Recently, on two-way roads, a 2+1 lane treatment has been implemented to prevent head-on and median cross-over crashes. The treatment allows overtaking to occur where there is an overtaking lane (2nd lane) occurring and swapping sides every few kilometres for traffic in both direction of travel. The 2+1 treatment may create more compact and slower conditions, but allows for overtaking in certain sections in both directions. Driver frustration is reduced due to frequent overtaking opportunities.

Swedish experience indicates a 50% reduction in fatal crashes when compared to a single carriageway road, achieved largely by eliminating head-on crashes and a transfer of fatal crashes to minor injury crashes (Bergh, Carlsson & Larsson, 2003).

Though not proven, many motorbike riders have expressed concern on the possible severe outcome in the event of colliding with the barrier compared with other barrier types. Another concern is the reported increase in the frequency and cost of maintenance due to impacts on the wire rope barrier

4.1.3 Centreline Treatments and Painted Medians

Literature suggests that wide centreline treatments can reduce the number of head-on and serious injury crashes. These have been used along the Bruce Highway with significant reductions (75%) in head-on crashes during the two years post installation.

Other centreline treatments that have also been successful in the reducing head-on crashes when there is limited median width available include the installation of central hatching and painted medians. These could be further enhanced by incorporating profiled centreline marking.

4.1.4 Overtaking Lanes

Overtaking lanes enable drivers to bypass slow moving vehicles and reduce driver frustration and inappropriate overtaking. An overtaking lane provides increased road capacity and helps to reduce the incidence of head-on collision due to overtaking manoeuvres.

In Queensland, only 3% of head-on crashes are due to overtaking, hence their use as a road safety improvement measure should be limited to sites with high number of head-on crashes due to overtaking, and severe sight distance restriction (i.e. not appropriate as a network wide treatment for head-on crashes).

4.1.5 Shoulder and Pavement Edge Break Treatment

Adequate sealed shoulder width makes it easy for errant drivers to re-enter the travel lanes, and prevent them leaving the road and over-steering which do lead to a head-on crash.

4.2 Run off-road Countermeasures

4.2.1 Shoulder Treatment

The provision of a sealed and unsealed shoulder provides an area whereby a vehicle may successfully recover during a run-off-road event. The literature review indicated significant run-off-road casualty crash reductions from the provision of wider shoulders, particularly where none existed previously.

4.2.2 Shoulder Rumble Strip

Profile edge lining, including shoulder rumble strips and audio tactile edge lines, consist of series of grooves or raised strips placed along the road shoulder to alert the driver when leaving the road. Austroads (2012) derived a crash reduction of 40% for run-off-road crashes for the installation of profile edge lines and is considered a successful treatment for run-off road crashes.

4.2.3 Roadside Hazard Treatment

Ideally the clear zone should be free of hazards. It has been shown that the relative risk of run-off-road casualty crashes reduces with increasing clear zone width. Where possible, roadside hazards should be removed, particularly on curves.

If a hazard is unable to be removed, then road users should be shielded from the hazard by a safety barrier. Barriers should be used where the potential damage caused by the hazard is greater than that of the barrier itself. As discussed previously, flexible barriers have been found to significantly reduce the severity of crash outcomes.

All barrier types are hazardous to motorcyclists with a high risk of sustaining serious injury or death from sliding into or colliding with the barrier. Barrier systems can be made more motorcycle friendly by shielding the barrier posts, modifying or replacing posts with more forgiving post shapes or covering exposed posts with specifically designed impact attenuators (Austroads 2014b).

4.3 Other Countermeasures

4.3.1 Curve Treatments and Speed Management Measures

The crash analysis showed that 56% of head-on injury crashes and 44% of run-off-road injury crashes occurred on horizontal curves and 42% of head-on injury crashes and 31% of run-off-road injury crashes occurred on vertical grades, dips or crests. This highlights the importance of the treatment of curves and the provision of good, clear curve delineation with appropriate advanced warning to allow road users to predict the road alignment and adjust their approach speeds accordingly.

Curve widening and improvements may prevent vehicles from travelling outside their lane and closer to the centre of the road. These include increasing the radius, providing transition curves between the straight and the bend, eliminating compound curves and improving superelevation.

Speed has a major impact on crash severity, so measures to provide safe travel speeds will lead to improve road safety. Engineering measures to reduce and manage operating speeds on roads include the

- advance warning signs to raise attention levels of curves and hazards and slow down motorists
- chevron alignment markers (CAMs) – used to indicate the presence and severity of curves
- speed advisory signs – used to aid motorists of the comfortable travel speed of a curve
- vehicle activated signs – when triggered by approaching speed exceeding the threshold speed limit, the sign displays the hazard
- transverse rumble strips – audio-tactile treatment applied transverse or across the travel lane to warn of approaching curves
- consistent application of curve design and treatments along a route
- innovative road pavement markings, additional marker posts, and other perceptual countermeasures may be useful to highlight deceptive corners and may aid motorists in adjusting their speed prior to entering the curve.

4.3.2 Others

The crash data analysis showed that motorcyclists are overrepresented in head-on and run-off road injury crashes and heavy vehicles over represented in head-on and run-off road fatal crashes in Queensland. Due consideration should be given to these vehicles when determining treatments for popular motorcycle routes and road sections or routes with a high proportion of heavy vehicles.

Given that 29% of head-on injury crashes and 46% run-off-road injury crashes occurred during dusk, dawn or darkness, it highlights the importance of good road delineation and the provision of consistent and predictable road alignment.

About 27% of head-on injury crashes and 42% run-off-road injury crashes occurred on a wet surface. This highlights the importance of good shoulder and road drainage with good skid resistant pavement surface, particularly on curves.

Pavement edge break (vertical edge > 6.35 cm) increases crash severity due to in steep angle entry by vehicles and over-steering which may lead to head-on and opposite side run-off-road crash). Regular maintenance of edge breaks is essential.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The key findings from the analysis of head-on, run-off-road and out-of-control injury crashes on Queensland roads include the following:

- Forty per cent of all injury crashes on QLD roads resulted in fatal or serious injury (FSI)
- Head-on crashes account for 4% of all injury crashes, 6% of FSI on QLD roads; 7% of FSI on state-controlled roads crashes during the five-year period
- Head-on crashes are more severe than other crash types - about 61% of all head-on crashes resulted in fatal or serious injury compared to 40% for all injury crash types
- the proportion of FSI head-on crashes is higher on state-controlled roads than those on locally controlled roads (64% of the head-on crashes on state-controlled roads were FSI crashes compared to 56% on locally controlled roads)
- Only 3% of all head-on injury crashes on QLD roads was due to overtaking vehicles, hence overtaking lanes should be provided as a safety measure only at specific sites with severe sight distance restriction or where head-on crashes due to overtaking is high. As a mass action program, overtaking lanes will have minimal impact on safety on Queensland roads, but will increase road capacity and improve vehicle operation and performance.
- Run-off road crashes including out-of-control crashes represent 33% of FSI on QLD roads; 36% of FSI on state-controlled roads
- Young controllers (17-24 years old) make up the largest proportion of the primary vehicle controllers involved in head-on, run-off-road and out-of-control crashes injury crashes
- As primary vehicle controller, male drivers accounted for about 70% of the head-on, run-off-road and out-of-control crashes injury crashes
- The risk of a fatal head-on crash was higher for heavy vehicles compared to other vehicle types
- Motorcycles/mopeds were over-represented in head-on, run-off-road and out-of-control crashes injury crashes
- The top five contributing factors as recorded for these crash types were disobeying the road rules, young adults 17-24 age old, road condition and controller condition and alcohol related.

Based on a review of the relevant literature and the crash analysis the following engineering treatments, which may be implemented to reduce the incidence of or severity of head-on and run-off-road crashes as a mass action treatment.

- Road centreline treatment (central hatching and wide centreline with audio-tactile line marking) to reduce the incidence of head-on and cross median crashes
- Median barriers and 2+1 lane treatment to prevent head-on crashes and reduce the incidence and severity of cross median crashes
- Improve signage, delineation and speed reduction measures especially on curves to reduce the incidence of head-on and run-off-road crashes – provide chevron alignment markers, guideposts, edge lines, raised reflective pavement markers, vehicle activated signs (VAS), advisory speed signs
- Improve skid resistance and road surface condition, especially at high risk curves

- Roadside hazard treatment such as hazard protection with safety barriers, hazard removal (point objects such as trees, poles/posts, etc.), application of impact attenuators, batter slopes management and replacing non-frangible poles with frangible ones
- Shoulder treatment – sealing, widening and edge treatment to make it easy for errant drivers to re-enter the travel lanes, and avoid steep angle entry which may lead to head-on and run-off-road crash, opposite site due to over-steering.

5.2 Recommendations

Key recommendations for policy actions and/or further research derived from the literature review and crash analysis include:

- Improve the safety on curves – this recommendation is based on the finding that 52% of head-on, 44% of run-off-road and 47% of out-of-control injury crashes occurred on curves
- Comprehensive review and analysis including on-site of high crash sites for the following crash types:
  - motorcycles/mopeds injury crashes (over-represented in head-on, run-off-road and out-of-control crashes injury crashes)
  - heavy vehicle crashes (high risk of fatal head-on crash)
  - fatigue related crashes on state control roads
- Using curvature data from the ANRAM coded data of the state-controlled roads, investigate the relationships between curve radii and crashes, especially with head-on and run-off-road crashes.

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APPENDIX A STATE-CONTROLLED ROADS HIGH HEAD-ON CRASH SECTIONS

Table A 1: Top 50 state-controlled roads with high number of head-on injury crashes (2007-11)

Road Sections	Fatal – HO crashes	Hospitalisation – HO crashes	Medical treatment – HO crashes	Minor injury – HO crashes	Total – HO crashes	Annual average HO crash cost
10E	9	5	3	4	21	$15,125,663
18B	8	6	3	1	18	$13,546,560
10A	7	17	11	2	37	$12,900,385
10B	7	12	8	2	29	$12,470,480
10C	7	9	2	1	19	$12,115,146
10L	6	3	1	0	10	$10,017,773
17B	5	14	4	1	24	$9,264,691
40A	5	10	2	0	17	$8,921,731
10H	5	10	1	1	17	$8,907,938
10G	4	15	3	5	27	$7,717,328
20A	4	11	6	1	22	$7,458,508
10F	4	6	5	2	17	$7,078,955
10P	4	5	5	2	16	$7,005,802
490	4	4	1	0	9	$6,831,947
32A	3	20	11	6	40	$6,632,240
10D	3	9	4	4	20	$5,662,718
150B	3	8	2	1	14	$5,524,037
10M	3	7	0	1	11	$5,408,122
12A	3	4	5	1	13	$5,295,572
40B	3	4	3	2	12	$5,260,398
22A	3	4	0	2	9	$5,196,254
10N	2	11	7	2	22	$4,228,500
25A	2	12	1	2	17	$4,173,364
163	2	6	2		10	$3,740,654
133	2	5	3	0	10	$3,688,884
18A	2	5	2	2	11	$3,682,680
42A	2	5	1	4	12	$3,676,476
32B	2	5	1	2	10	$3,661,298
33B	2	3	2	3	10	$3,543,964
203	1	8	2	0	11	$2,257,470
U96	1	7	3	1	12	$2,213,288
401	1	7	2	1	11	$2,191,906
207	1	6	1	2	10	$2,104,961
194	1	6	1	1	9	$2,097,373
40C	1	5	2	2	10	$2,053,191

Road Sections	Fatal – HO crashes	Hospitalisation – HO crashes	Medical treatment – HO crashes	Minor injury – HO crashes	Total – HO crashes	Annual average HO crash cost
111	1	1	2	4	8	$1,775,759
201	0	9	3	0	12	$722,514
202	0	8	6	1	15	$721,095
126	0	9	0	3	12	$681,136
206	0	6	6	3	15	$589,968
402	0	7	3	0	10	$576,210
4023	0	7	2	0	9	$554,828
407	0	7	1	1	9	$541,036
134	0	6	3	5	14	$541,001
19A	0	6	2	1	9	$489,265
10K	0	5	3	0	8	$429,905
642	0	5	1	4	10	$417,498
200	0	3	6	1	10	$355,334
U18B	0	3	4	1	8	$312,571
150A	0	1	6	4	11	$231,796

Table A 2: Top 50 state-controlled roads with high collective head-on crash risk ranked by crash cost per km (2007-11)

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total HO injury crashes	Total HO FSI crashes	Annual average HO injury crashes per km	Annual average HO injury crash cost per km	Annual average HO injury crashes per 100M veh-km	Annual average HO injury crash cost per 1000 veh-km
9901	1.78	7708	1	1	0.112	$915,443	3.99	$326.00
904	6.63	16330	4	4	0.121	$748,359	2.02	$126.00
U27	6.45	NA	3	3	0.093	$516,609	NA	NA
142	9.97	9833	4	4	0.08	$497,655	2.24	$138.00
208	4.66	15107	4	3	0.172	$385,660	3.11	$70.00
914	10.56	NA	4	4	0.076	$322,470	NA	NA
U95	7.1	15842	5	4	0.141	$263,426	2.44	$46.00
150B	25.72	19389	14	11	0.109	$214,776	1.54	$30.00
110	9.56	19045	4	3	0.084	$186,546	1.20	$26.00
40A	50.53	6309	17	15	0.067	$176,563	2.92	$76.00
32A	48.915	4328	40	23	0.164	$135,587	10.35	$86.00
133	27.42	12890	10	7	0.073	$134,533	1.55	$28.00
111	13.24	11896	8	2	0.121	$134,121	2.78	$30.00
647	14.021	23472	6	3	0.086	$131,227	1.00	$16.00
U96	17.27	13158	12	8	0.139	$128,158	2.89	$26.00
25A	41.6	12216	17	14	0.082	$100,321	1.83	$22.00
185	19.286	9957	7	4	0.073	$99,196	2.00	$28.00

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total HO injury crashes	Total HO FSI crashes	Annual average HO injury crashes per km	Annual average HO injury crash cost per km	Annual average HO injury crashes per 100M veh-km	Annual average HO injury crash cost per 1000 veh-km
207	24.97	6906	10	7	0.08	$84,300	3.18	$34.00
407	6.65	12763	9	7	0.271	$81,359	5.81	$18.00
118	2.3	24901	2	2	0.174	$63,611	1.91	$6.00
117	1.91	15758	2	1	0.209	$49,494	3.64	$8.00
134	11.46	13177	14	6	0.244	$47,208	5.08	$10.00
200	7.72	21599	10	3	0.259	$46,028	3.29	$6.00
530	3.852	11995	2	2	0.104	$37,981	2.37	$8.00
649	2.53	17901	2	1	0.158	$37,365	2.42	$6.00
402	15.61	3620	10	7	0.128	$36,913	9.70	$28.00
126	19.06	18589	12	9	0.126	$35,736	1.86	$6.00
900	7.7	33544	5	3	0.13	$32,263	1.06	$2.00
302	7.5	13219	4	3	0.107	$30,273	2.21	$6.00
U91	11.95	17912	7	4	0.117	$28,700	1.79	$4.00
831	5.47	12891	3	2	0.11	$28,134	2.33	$6.00
809	6.23	32964	3	2	0.096	$26,916	0.80	$2.00
150A	8.63	28356	11	1	0.255	$26,859	2.46	$2.00
206	22.105	6063	15	6	0.136	$26,689	6.13	$12.00
2015	11.04	1106	4	4	0.072	$26,504	17.95	$66.00
496	12.27	5868	6	4	0.098	$26,209	4.57	$12.00
140	14.29	10235	5	5	0.07	$25,596	1.87	$6.00
136	10.05	22550	4	3	0.08	$23,964	0.97	$2.00
2071	7.25	5679	3	2	0.083	$23,129	3.99	$12.00
130	8.07	9801	5	2	0.124	$22,660	3.46	$6.00
U20	7.41	27402	3	2	0.081	$22,630	0.81	$2.00
U14	14.31	41829	5	4	0.07	$21,942	0.46	$2.00
4023	27.11	429	9	7	0.066	$20,466	42.37	$130.00
9905	8.24	13604	3	2	0.073	$20,350	1.47	$4.00
2001	9.953	4444	5	2	0.1	$19,758	6.19	$12.00
U18B	16.19	35088	8	3	0.099	$19,306	0.77	$2.00
11A	11.29	26512	6	2	0.106	$18,091	1.10	$2.00
11B	18.48	29275	8	3	0.087	$17,660	0.81	$2.00
102	5.69	26964	2	1	0.07	$16,614	0.71	$2.00
114	14.03	22034	5	2	0.071	$15,000	0.89	$2.00

Table A 3: Top 50 state-controlled roads with the highest individual head-on crash risk ranked by crash cost per $1000 veh-km (2007-11)

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total HO injury crashes	Total HO FSI crashes	Annual average ROR injury crashes per km	Annual average HO injury crash cost per km	Annual average HO injury crashes per 100M veh-km	Annual average HO injury crash cost per 1000 veh-km
4808	17.77	208	1	1	0.011	$91,699	14.82	$1,208.00
6404	10.72	579	2	1	0.037	$153,956	17.66	$728.00
1751	4.3	2580	1	1	0.047	$379,392	4.94	$402.00
476	58.98	215	1	1	0.003	$27,626	4.32	$352.00
9901	1.78	7708	1	1	0.112	$915,443	3.99	$326.00
665	15.1	933	1	1	0.013	$107,913	3.89	$316.00
1204	13.86	2137	3	2	0.043	$235,683	5.55	$302.00
462	24.15	34	1	1	0.008	$3,030	66.75	$244.00
94B	163.73	119	2	2	0.002	$10,399	5.63	$240.00
2020	18.44	1502	6	5	0.065	$105,395	11.87	$192.00
4023	27.11	429	9	7	0.066	$20,466	42.37	$130.00
32A	48.92	4328	40	23	0.164	$135,587	10.35	$86.00
40B	68.72	2439	12	7	0.035	$76,548	3.92	$86.00
1003	19.28	3057	6	2	0.062	$92,747	5.58	$84.00
6106	21.89	168	2	1	0.018	$4,319	29.79	$70.00
2015	11.04	1106	4	4	0.072	$26,504	17.95	$66.00
481	14.21	555	4	2	0.056	$12,335	27.78	$60.00
40C	45.72	2856	10	6	0.044	$44,908	4.20	$44.00
201	36.19	1401	12	9	0.066	$19,964	12.97	$40.00
5472	57.35	86	1	1	0.003	$1,276	11.10	$40.00
6801	219.15	26	1	1	0.001	$334	9.78	$36.00
411	12.88	967	2	2	0.031	$11,359	8.80	$32.00
8506	9.92	1338	2	2	0.04	$14,756	8.26	$30.00
4161	58.21	155	2	1	0.007	$1,624	12.14	$28.00
402	15.61	3620	10	7	0.128	$36,913	9.70	$28.00
8509	13.04	2211	4	4	0.061	$22,448	7.61	$28.00
2011	9.07	905	2	1	0.044	$8,902	13.35	$26.00
627	25.46	1593	6	4	0.047	$13,174	8.11	$22.00
552	178.54	53	1	1	0.001	$410	5.74	$20.00
486	22.63	427	1	1	0.009	$3,233	5.67	$20.00
407	6.65	12763	9	7	0.271	$81,359	5.81	$18.00
474	50.57	664	3	3	0.012	$4,339	4.90	$18.00
6632	69.63	291	3	1	0.009	$1,665	8.11	$16.00
4962	19.84	809	2	1	0.02	$4,765	6.83	$16.00

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total HO injury crashes	Total HO FSI crashes	Annual average ROR injury crashes per km	Annual average HO injury crash cost per km	Annual average HO injury crashes per 100M veh-km	Annual average HO injury crash cost per 1000 veh-km
2001	9.95	4444	5	2	0.1	$19,758	6.19	$12.00
206	22.11	6063	15	6	0.136	$26,689	6.13	$12.00
496	12.27	5868	6	4	0.098	$26,209	4.57	$12.00
653	28.49	1341	3	2	0.021	$5,401	4.30	$12.00
2071	7.25	5679	3	2	0.083	$23,129	3.99	$12.00
141	54.65	1089	7	2	0.026	$4,129	6.45	$10.00
1305	13.13	1971	3	1	0.046	$6,727	6.35	$10.00
134	11.46	13177	14	6	0.244	$47,208	5.08	$10.00
205	24.08	2474	5	2	0.042	$8,167	4.60	$10.00
8108	18.46	2173	3	2	0.033	$8,337	4.10	$10.00
495	40.68	1323	4	2	0.02	$4,648	4.07	$10.00
104	30.42	3247	7	4	0.046	$10,820	3.88	$10.00
4806	38.13	1405	4	2	0.021	$4,597	4.09	$8.00
536	38.28	251	1	0	0.005	$559	5.71	$6.00
2050	10.9	1568	2	0	0.037	$2,658	6.41	$4.00
485	18.56	650	1	0	0.011	$1,152	4.54	$4.00

APPENDIX B STATE-CONTROLLED ROADS HIGH RUN-OFF-ROAD CRASH SECTIONS

Table B 1: Top 50 state-controlled roads with high number of run-off-road Injury crashes (2007-11)

Road Sections	Fatal – ROR crashes	Hospitalisation – ROR crashes	Medical treatment – ROR crashes	Minor injury – ROR crashes	Total – ROR crashes	Annual average crash cost
10A	8	148	128	39	323	$26,895,222
10B	10	39	31	10	90	$19,886,539
18A	8	61	65	41	175	$19,199,130
12A	3	112	110	40	265	$15,737,020
20A	3	70	43	18	134	$11,065,120
202	5	19	13	6	43	$9,860,829
10J	5	18	11	1	35	$9,706,970
120	5	17	10	3	35	$9,627,614
10G	4	32	23	13	72	$9,449,254
10P	4	27	17	9	57	$8,924,849
10M	3	48	20	10	81	$8,903,289
10K	4	25	12	6	47	$8,648,871
17B	3	39	28	18	88	$8,476,681
16A	4	22	7	4	37	$8,307,330
10E	3	35	23	5	66	$7,978,511
210A	3	32	21	4	60	$7,708,703
10C	3	27	20	15	65	$7,405,037
10F	3	25	17	7	52	$7,133,878
10D	2	40	26	22	90	$6,907,936
40A	3	24	9	8	44	$6,897,263
10L	3	21	18	5	47	$6,847,473
10N	2	25	25	14	66	$5,728,562
103	2	25	15	3	45	$5,431,271
32A	2	19	19	15	55	$5,168,949
25A	2	19	21	9	51	$5,166,179
206	2	20	18	2	42	$5,122,065
U13C	1	34	32	7	74	$4,853,990
10H	1	33	17	9	60	$4,475,295
196	1	32	18	6	57	$4,400,758
642	1	28	22	21	72	$4,307,506
33B	2	6	18	6	32	$4,128,290
401	1	20	28	7	56	$3,744,334
203	1	20	13	4	38	$3,400,847
16B	1	19	16	5	41	$3,399,427
U14	1	18	12	3	34	$3,225,572

Road Sections	Fatal – ROR crashes	Hospitalisation – ROR crashes	Medical treatment – ROR crashes	Minor injury – ROR crashes	Total – ROR crashes	Annual average crash cost
U12A	0	35	26	10	71	$3,192,131
18B	1	17	10	4	32	$3,117,246
150B	1	15	15	9	40	$3,115,792
N239	1	15	14	4	34	$3,056,467
19A	1	14	10	5	30	$2,905,378
22A		23	16	7	46	$2,077,725
11B	0	23	10	7	40	$1,949,436
204	0	19	16	6	41	$1,777,527
40B	0	16	17	7	40	$1,587,041
U18B	0	16	15	9	40	$1,559,455
46A	0	17	11	4	32	$1,509,138
163	0	15	11	9	35	$1,400,778
18D		14	11	5	30	$1,297,270
301	0	13	10	8	31	$1,225,503
134	0	12	13	7	32	$1,208,906

Table B 2: Top 50 state-controlled roads with the highest collective run-off-road crash risk ranked by crash cost per km (2007-11)

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total ROR injury crashes	Total ROR FSI crashes	Annual average ROR injury crashes per km	Annual average ROR injury crash cost per km	Annual average ROR injury crashes per 100M veh-km	Annual average ROR injury crash cost per 1000 veh-km
120	17.83	29741	35	22	0.393	$539,967	3.62	$50.00
U18A	10.95	29779	22	6	0.402	$344,252	3.70	$32.00
U20	7.41	27402	21	9	0.567	$326,061	5.67	$32.00
103	17.92	38171	45	27	0.502	$303,169	3.61	$22.00
210A	29.03	NA	60	35	0.413	$265,570	NA	NA
9905	8.24	13604	16	6	0.388	$261,395	7.82	$52.00
206	22.11	6063	42	22	0.38	$231,715	17.17	$104.00
U14	14.31	41829	34	19	0.475	$225,407	3.11	$14.00
U15	11.87	29421	30	10	0.505	$221,797	4.71	$20.00
153	12.73	35631	25	13	0.393	$212,783	3.02	$16.00
18A	91.8	16010	175	69	0.381	$209,141	6.52	$36.00
12A	79.32	75359	265	115	0.668	$198,402	2.43	$8.00
10A	142.4	30209	323	156	0.454	$188,871	4.11	$18.00
U12A	17.33	80437	71	35	0.819	$184,197	2.79	$6.00
101	7.4	48582	25	15	0.676	$171,584	3.81	$10.00
906	1.55	NA	6	3	0.775	$165,278	NA	NA

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total ROR injury crashes	Total ROR FSI crashes	Annual average ROR injury crashes per km	Annual average ROR injury crash cost per km	Annual average ROR injury crashes per 100M veh-km	Annual average ROR injury crash cost per 1000 veh-km
20A	74.93	9209	134	73	0.358	$147,671	10.64	$44.00
U93	1.19	5363	3	2	0.504	$140,912	25.76	$72.00
407	6.65	12763	19	10	0.571	$134,792	12.27	$28.00
913	6.05	NA	17	9	0.562	$130,255	NA	NA
U98	7.2	31282	21	10	0.583	$126,604	5.11	$12.00
116	9.62	30493	25	12	0.52	$115,843	4.67	$10.00
U90	4.75	22065	10	7	0.421	$115,500	5.23	$14.00
200	7.72	21599	19	10	0.492	$112,537	6.24	$14.00
134	11.46	13177	32	12	0.558	$105,489	11.61	$22.00
11B	18.48	29275	40	23	0.433	$105,489	4.05	$10.00
102	5.69	26964	13	7	0.457	$105,268	4.64	$10.00
1122	6.81	22149	16	8	0.47	$104,977	5.81	$12.00
406	7.78	27405	22	8	0.566	$103,059	5.65	$10.00
U16	11.3	47118	24	13	0.425	$97,665	2.47	$6.00
809	6.23	32964	12	7	0.385	$97,140	3.20	$8.00
105	11.55	29204	22	13	0.381	$96,650	3.58	$10.00
U18B	16.19	35088	40	16	0.494	$96,322	3.86	$8.00
U19	9.65	15066	22	10	0.456	$95,247	8.29	$18.00
135	3.82	24259	7	4	0.366	$93,391	4.14	$10.00
204	19.27	20929	41	19	0.426	$92,243	5.57	$12.00
11A	11.29	26512	20	12	0.354	$89,238	3.66	$10.00
U88	10.06	28464	24	9	0.477	$84,986	4.59	$8.00
301	14.85	21207	31	13	0.418	$82,525	5.39	$10.00
130	8.07	9801	21	6	0.52	$82,167	14.55	$22.00
1102	6.42	18933	12	6	0.374	$81,904	5.41	$12.00
837	0.99	16182	2	1	0.404	$81,639	6.85	$14.00
612	8.14	23335	15	7	0.369	$77,143	4.33	$10.00
647	14.02	23472	28	11	0.399	$76,429	4.66	$8.00
839	0.29	6142	1	0	0.683	$72,974	30.45	$32.00
900	7.7	33544	19	3	0.494	$63,974	4.03	$6.00
1411	6.32	5270	11	3	0.348	$59,607	18.10	$30.00
U94	4.27	18424	8	2	0.375	$57,847	5.57	$8.00
915	2.11	NA	4	1	0.379	$51,996	NA	NA
905	3.8	34891	7	1	0.368	$49,381	2.89	$4.00

Table B 3: Top 50 state-controlled roads with the highest individual run-off-road crash risk ranked by crash cost per $1000 veh-km (2007-11)

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total ROR injury crashes	Total ROR FSI crashes	Annual average ROR injury crashes per km	Annual average ROR injury crash cost per km	Annual average ROR injury crashes per 100M veh-km	Annual average ROR injury crash cost per 1000 veh-km
6404	10.72	579	9	6	0.168	$337,194	79.46	$1,596.00
5109	17.88	15	1	1	0.011	$4,091	204.30	$748.00
2134	14.37	894	7	4	0.097	$131,211	29.87	$402.00
8554	11.27	179	6	3	0.107	$23,951	163.50	$368.00
475	55.67	299	11	2	0.04	$33,297	36.23	$306.00
232	99.18	207	10	7	0.02	$21,502	26.65	$284.00
4981	10.5	1899	9	3	0.171	$178,714	24.74	$258.00
3341	4.67	178	1	1	0.043	$15,664	66.10	$242.00
1204	13.86	2137	14	9	0.202	$165,514	25.90	$212.00
4023	27.11	429	19	11	0.14	$32,939	89.45	$210.00
4196	25.52	81	2	2	0.016	$5,733	52.85	$194.00
3401	21.02	58	1	1	0.01	$3,480	45.14	$166.00
2214	19.26	213	4	3	0.042	$12,505	53.41	$160.00
493	20.31	985	18	12	0.177	$49,538	49.30	$138.00
2005	23.63	215	5	3	0.042	$10,513	53.93	$134.00
6801	219.15	26	5	3	0.005	$1,134	48.92	$122.00
349	16.99	98	1	1	0.012	$4,306	32.85	$120.00
4608	23.45	73	1	1	0.009	$3,119	32.01	$118.00
464	34.47	152	3	3	0.017	$6,367	31.38	$114.00
5332	3.78	467	1	1	0.053	$19,363	31.06	$114.00
3363	10.39	171	1	1	0.019	$7,041	30.84	$112.00
6141	25.57	153	2	2	0.016	$5,722	28.04	$102.00
481	14.21	555	6	3	0.084	$19,958	41.67	$98.00
8506	9.92	1338	8	5	0.161	$43,359	33.04	$88.00
6507	7.57	336	2	1	0.053	$10,666	43.09	$86.00
303	10.52	759	5	3	0.095	$23,615	34.32	$86.00
4356	39.46	146	3	2	0.015	$4,250	28.63	$80.00
476	58.98	215	8	4	0.027	$5,943	34.59	$76.00
405	46.65	692	17	11	0.073	$19,408	28.85	$76.00
4832	13.35	796	6	3	0.09	$21,244	30.95	$74.00
495	40.68	1323	27	17	0.133	$35,487	27.48	$74.00
642	55.95	2878	72	29	0.257	$76,995	24.51	$74.00
5124	44.36	19	1	0	0.005	$482	66.78	$72.00
626	14.88	602	5	3	0.067	$15,768	30.59	$72.00

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total ROR injury crashes	Total ROR FSI crashes	Annual average ROR injury crashes per km	Annual average ROR injury crash cost per km	Annual average ROR injury crashes per 100M veh-km	Annual average ROR injury crash cost per 1000 veh-km
U93	1.19	5363	3	2	0.504	$140,912	25.76	$72.00
188	25.24	255	3	2	0.024	$6,644	25.59	$72.00
2020	18.44	1502	17	7	0.184	$37,868	33.63	$70.00
486	22.63	427	5	3	0.044	$10,978	28.34	$70.00
3402	43.03	305	6	4	0.028	$7,473	25.05	$68.00
8101	27.19	920	15	6	0.11	$21,695	32.85	$64.00
485	18.56	650	6	3	0.065	$15,280	27.26	$64.00
213	46.49	716	15	8	0.065	$15,807	24.69	$60.00
518	10.43	611	3	1	0.058	$11,115	25.81	$50.00
471	132.1	260	16	7	0.024	$4,707	25.52	$50.00
491	116.92	224	12	5	0.021	$4,055	25.14	$50.00
5324	32.85	175	3	1	0.018	$3,109	28.60	$48.00
3403	22.86	55	1	0	0.009	$935	43.78	$46.00
646	13.53	198	2	0	0.03	$3,161	40.96	$44.00
839	0.29	6142	1	0	0.683	$72,974	30.45	$32.00
327	35.77	118	2	0	0.011	$1,195	26.07	$28.00

APPENDIX C STATE-CONTROLLED ROADS HIGH OUT-OF-CONTROL CRASH SECTIONS

Table C 1: Top state-controlled roads with high number of out-off-control Injury crashes (2007-11)

Road Sections	Fatal – OOC crashes	Hospitalisation – OOC crashes	Medical treatment – OOC crashes	Minor injury – OOC crashes	Total – OOC injury crashes	Annual average OOC crash cost
90D	4	4	5	1	14	$6,925,061
12A	2	27	24	12	65	$5,838,307
18A	2	16	12	5	35	$4,723,934
10A	1	29	14	5	49	$4,088,187
10D	1	12	3	3	19	$2,594,226
17B	1	9	6	5	21	$2,454,091
10F	1	10	3	3	17	$2,447,922
495	1	8	6	0	15	$2,342,995
10C	1	7	3	1	12	$2,213,288
N239	1	5	6	0	12	$2,123,539
185	1	5	2	0	8	$2,038,013
2020	1	5	2	0	8	$2,038,013
202	1	4	3	0	8	$1,986,242
25B	1	3	5	1	10	$1,963,442
15A	1	3	3	1	8	$1,920,679
20A	0	15	5	9	29	$1,272,489
32A	0	13	11	2	26	$1,201,352
4023	0	14	4	2	20	$1,124,834
401	0	12	7	3	22	$1,050,263
642	0	11	4	3	18	$912,966
10G	0	10	6	4	20	$890,166
U13C	0	9	5	5	19	$803,221
U12A	0	9	4	1	14	$751,484
22A	0	9	3	2	14	$737,692
U18B	0	9	3	2	14	$737,692
10N	0	8	5	3	16	$714,891
10M	0	8	3	3	14	$672,128
10E	0	8	4	0	12	$670,743
10H	0	6	7	4	17	$618,938
10B	0	5	9	1	15	$565,782
15B	0	7	2	0	9	$554,828
206	0	6	4	1	11	$532,028
18D	0	6	3	2	11	$518,235
89B	0	6	3	1	10	$510,646
33B	0	5	5	1	11	$480,257

Road Sections	Fatal – OOC crashes	Hospitalisation – OOC crashes	Medical treatment – OOC crashes	Minor injury – OOC crashes	Total – OOC injury crashes	Annual average OOC crash cost
19B	0	5	5	0	10	$472,668
210A	0	5	3	2	10	$445,083
35A	0	5	3	0	8	$429,905
10P	0	4	6	0	10	$420,897
32B	0	5	2	1	8	$416,113
203	0	4	5	2	11	$414,693
900	0	4	4	2	10	$393,312
U27	0	4	3	1	8	$364,342
10L	0	4	3	1	8	$364,342
92C	0	4	2	2	8	$350,549
171	0	3	4	2	9	$320,160
835	0	3	3	3	9	$306,367
U18A	0	2	5	1	8	$260,800
126	0	2	5	1	8	$260,800
27B	0	1	6	1	8	$209,029

Table C 2: Top 50 state-controlled roads with the highest collective out-of-control crash risk ranked by crash cost per km (2007-11)

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total OOC injury crashes	Total OOC FSI crashes	Annual average OOC injury crashes per km	Annual average OOC injury crash cost per km	Annual average OOC injury crashes per 100M veh-km	Annual average OOC injury crash cost per 1000 veh-km
208	4.66	15107	3	2	0.129	$369,962	2.34	$68.00
1122	6.81	22149	4	2	0.117	$256,300	1.45	$32.00
2029	7.55	NA	4	2	0.106	$229,353	NA	NA
U21	0.84	31288	2	1	0.476	$112,540	4.17	$10.00
2020	18.44	1502	8	6	0.087	$110,521	15.82	$202.00
185	19.29	9957	8	6	0.083	$105,673	2.28	$30.00
12A	79.32	75359	65	29	0.164	$73,605	0.60	$2.00
U93	1.19	5363	2	1	0.336	$67,850	17.17	$34.00
U27	6.45	NA	8	4	0.248	$56,487	NA	NA
U98	7.2	31282	6	5	0.167	$53,770	1.46	$4.00
913	6.05	NA	5	4	0.165	$51,899	NA	NA
U95	7.1	15842	5	5	0.141	$51,516	2.44	$8.00
900	7.7	33544	10	4	0.26	$51,079	2.12	$4.00
101	7.4	48582	6	5	0.162	$50,453	0.91	$2.00
U20	7.41	27402	5	5	0.135	$49,360	1.35	$4.00
840	5.51	NA	6	3	0.218	$48,976	NA	NA

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total OOC injury crashes	Total OOC FSI crashes	Annual average OOC injury crashes per km	Annual average OOC injury crash cost per km	Annual average OOC injury crashes per 100M veh-km	Annual average OOC injury crash cost per 1000 veh-km
407	6.65	12763	6	4	0.18	$48,358	3.87	$10.00
906	1.55	NA	1	1	0.129	$47,225	NA	NA
U18B	16.19	35088	14	9	0.173	$45,565	1.35	$4.00
833	7.88	19268	7	4	0.178	$45,273	2.53	$6.00
U12A	17.33	80437	14	9	0.162	$43,363	0.55	$2.00
1720	1.74	2279	1	1	0.115	$42,041	13.82	$50.00
4023	27.11	429	20	14	0.148	$41,491	94.16	$264.00
905	3.8	34891	2	2	0.105	$38,501	0.83	$4.00
904	6.63	16330	3	3	0.09	$33,101	1.52	$6.00
U15	11.87	29421	6	5	0.101	$32,615	0.94	$4.00
4906	6.87	4267	3	3	0.087	$31,944	5.61	$20.00
U90	4.75	22065	2	2	0.084	$30,801	1.05	$4.00
11A	11.29	26512	6	4	0.106	$29,705	1.10	$4.00
649	2.53	17901	1	1	0.079	$28,914	1.21	$4.00
U16	11.3	47118	7	3	0.124	$25,774	0.72	$2.00
32A	48.92	4328	26	13	0.106	$24,560	6.73	$16.00
206	22.11	6063	11	6	0.1	$24,068	4.50	$10.00
U18A	10.95	29779	8	2	0.146	$23,817	1.34	$2.00
406	7.78	27405	4	2	0.103	$22,529	1.03	$2.00
837	0.99	16182	1	0	0.202	$21,619	3.42	$4.00
489	13.42	17433	6	3	0.089	$20,105	1.41	$4.00
830	10	13990	5	2	0.1	$19,666	1.96	$4.00
U14	14.31	41829	6	3	0.084	$18,855	0.55	$2.00
835	17.69	23850	9	3	0.102	$17,319	1.17	$2.00
20A	74.93	9209	29	15	0.077	$16,982	2.30	$6.00
311	8.22	4792	4	1	0.097	$15,025	5.56	$8.00
126	19.06	18589	8	2	0.084	$13,683	1.24	$2.00
360	1.58	3548	1	0	0.127	$13,575	9.81	$10.00
145	7.05	6994	3	1	0.085	$12,529	3.33	$4.00
114	14.03	22034	6	1	0.086	$10,868	1.06	$2.00
8565	4.63	7494	2	0	0.086	$9,236	3.16	$4.00
810	1.9	12528	2	0	0.211	$7,988	4.60	$2.00
809	6.23	32964	3	0	0.096	$5,868	0.80	$0.00
H178	1.89	NA	1	0	0.106	$4,022	NA	NA

Table C 3: Top 50 state-controlled roads with the highest individual out-of-control crash risk ranked by crash cost per $1000 veh-km (2007-11)

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total OOC injury crashes	Total OOC FSI crashes	Annual average OOC injury crashes per km	Annual average OOC injury crash cost per km	Annual average OOC injury crashes per 100M veh-km	Annual average OOC injury crash cost per 1000 veh-km
7003	184.83	34	1	1	0.001	$8,816	8.77	$714.00
90D	219.53	139	14	8	0.013	$31,545	25.18	$622.00
3251	45.61	174	2	2	0.009	$37,330	13.83	$588.00
7708	169.08	71	2	1	0.002	$9,764	9.18	$378.00
3306	45.03	309	2	2	0.009	$37,811	7.87	$334.00
405	46.65	692	5	5	0.021	$74,565	8.49	$296.00
4023	27.11	429	20	14	0.148	$41,491	94.16	$264.00
3341	4.67	178	1	1	0.043	$15,664	66.10	$242.00
232	99.18	207	3	3	0.006	$17,905	8.00	$236.00
2020	18.44	1502	8	6	0.087	$110,521	15.82	$202.00
495	40.68	1323	15	9	0.074	$57,596	15.27	$120.00
7001	117.23	17	1	1	0.002	$624	27.91	$102.00
2214	19.26	213	2	2	0.021	$7,596	26.70	$98.00
572	84.62	52	2	2	0.005	$1,729	24.69	$90.00
4163	16.36	142	1	1	0.012	$4,471	23.59	$86.00
2005	23.63	215	2	2	0.017	$6,191	21.57	$78.00
6507	7.57	336	1	1	0.026	$9,663	21.54	$78.00
1720	1.74	2279	1	1	0.115	$42,041	13.82	$50.00
5807	112.37	49	2	1	0.004	$841	20.11	$48.00
4161	58.21	155	2	2	0.007	$2,513	12.14	$44.00
99B	255.34	77	5	4	0.004	$1,176	13.92	$42.00
4405	17.3	557	2	2	0.023	$8,457	11.36	$42.00
481	14.21	555	3	1	0.042	$8,157	20.84	$40.00
493	20.31	985	6	3	0.059	$13,964	16.43	$38.00
441	120.06	50	2	1	0.003	$673	18.24	$36.00
5332	3.78	467	1	0	0.053	$5,659	31.06	$34.00
U93	1.19	5363	2	1	0.336	$67,850	17.17	$34.00
2015	11.04	1106	2	2	0.036	$13,252	8.98	$32.00
95A	91.71	71	1	1	0.002	$798	8.46	$30.00
716	122	54	1	1	0.002	$600	8.25	$30.00
5107	38.84	178	1	1	0.005	$1,883	7.93	$30.00
19B	45.73	1051	10	5	0.044	$10,336	11.40	$26.00
193	14.08	667	2	1	0.028	$5,734	11.66	$24.00
4397	149.42	113	3	2	0.004	$1,030	9.74	$24.00

Road Section ID	Length (km)	AADT (weighted average)	Crash frequency		Collective risk		Individual risk	
			Total OOC injury crashes	Total OOC FSI crashes	Annual average OOC injury crashes per km	Annual average OOC injury crash cost per km	Annual average OOC injury crashes per 100M veh-km	Annual average OOC injury crash cost per 1000 veh-km
92C	148.14	297	8	4	0.011	$2,366	9.95	$22.00
93C	388.78	24	3	0	0.002	$165	17.89	$20.00
90B	61.26	271	4	1	0.013	$2,016	13.18	$20.00
476	58.98	215	2	1	0.007	$1,603	8.65	$20.00
14C	114.5	306	5	3	0.009	$2,170	7.82	$20.00
410	39.13	487	4	1	0.02	$3,156	11.51	$18.00
313	62.68	677	7	3	0.022	$4,646	9.04	$18.00
535	8.78	2309	3	1	0.068	$13,208	8.11	$16.00
2106	4.15	1261	1	0	0.048	$5,152	10.47	$12.00
360	1.58	3548	1	0	0.127	$13,575	9.81	$10.00
6801	219.15	26	1	0	0.001	$98	9.78	$10.00
5324	32.85	175	1	0	0.006	$651	9.53	$10.00
5705	114.56	140	3	0	0.005	$440	10.25	$8.00
6632	69.63	291	3	0	0.009	$921	8.11	$8.00
7103	210.71	20	1	0	0.001	$36	12.96	$4.00
5101	103.99	46	1	0	0.002	$73	11.54	$4.00