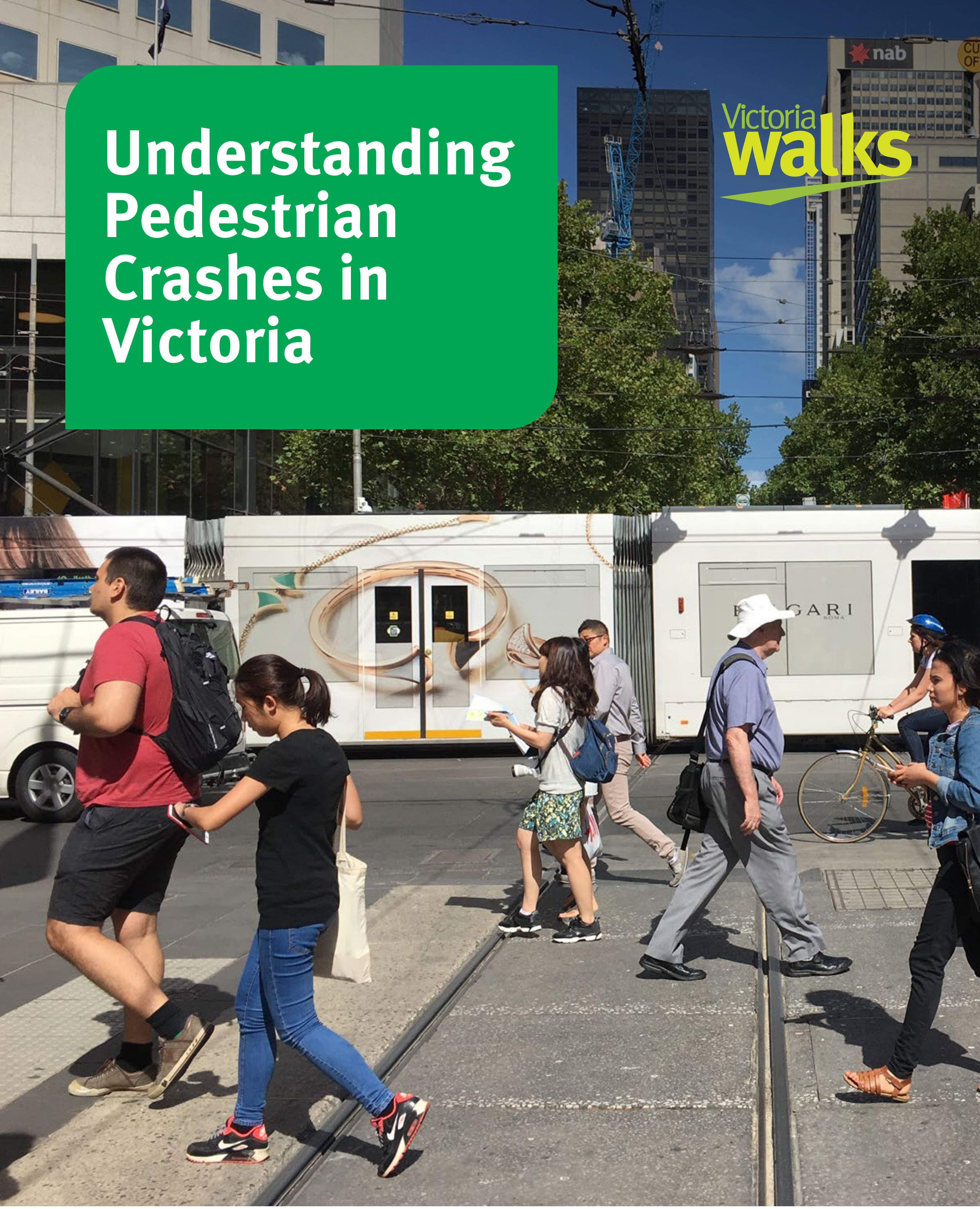
Understanding Pedestrian Crashes in Victoria



Victoria walks

MONASH University
Accident Research Centre

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Victoria Walks Inc is a walking health promotion charity working to get more Victorians walking more every day. Our vision is people walk whenever and wherever possible, within strong and vibrant communities, with resulting health benefits. Victoria Walks is supported by VicHealth.

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Executive Summary

This report seeks to provide the clearest possible picture of pedestrian crashes in Victoria given the available information and statistics.

With the support of a Transport Accident Commission (TAC) Community Road Safety Grant, Victoria Walks commissioned the Monash University Accident Research Centre to undertake the study, reviewing the relevant literature and analysing Victorian police, TAC, hospital and cause of death data.

Literature Review

Vehicle speed is a key risk factor for pedestrian injury and death. The higher the speed of a vehicle, the less time a driver has to stop and the higher the impact speed if they don't. The probability and severity of injury increases exponentially with vehicle speed. It is estimated that, for every 1 km/h increase in average vehicle speed, the number of injury crashes will rise by around three percent.

In Victoria the default urban speed limit was reduced from 60 km/h to 50 km/h in 2001. It has been estimated that fatal and serious injury crashes involving pedestrians were reduced by 25 to 40 percent as a result.

Older adults are over-represented in pedestrian fatalities and have an increased risk of severe injury. They are more likely to sustain fractures in a crash, and they have a high recovery time and likelihood of long-term disability. The effects of ageing on sensory, visual, perceptual and cognitive abilities may also increase risk on the road. However, it is important to recognise that older pedestrians are generally safe and cautious in their travel behaviour.

In terms of pedestrian behaviour increasing the likelihood of crashes, injury and death, the clear risk factor is intoxication. The proportion of pedestrian deaths involving intoxicated pedestrians (BAC over 0.5) in Australia has been previously estimated in the range of 30-45 percent. Pedestrians killed or seriously injured while intoxicated are more likely to be male and in younger age groups.

A number of studies suggest that a minority of pedestrians may possibly be distracted by mobile phones when crossing the street. However, no significant relationship with actual crashes seems to have been identified.

Drivers also contribute to increased pedestrian risk and the main factors include a lack of understanding the impacts of driving at high/inappropriate speeds in environments where there is a mix of vehicles and vulnerable road users, poor/inappropriate travel speed choice and non-compliance with speed limits, driving while distracted, and generally poor attitudes to pedestrian safety.

Vehicle design is a significant factor in the likelihood and consequences of a crash. SUVs have a greater risk of collision with pedestrians because the vehicle mass in front of the driver may obscure their vision of people walking, particularly children. In addition, pedestrians struck by an SUV or four-wheel-drive vehicle are more likely to incur serious head, thoracic, abdominal and spinal injuries. The typical trajectory for a person being hit by SUV or light truck involves being hit above their centre of gravity, so that being run-over by the vehicle is more likely.

Elements of streetscape design that separate pedestrians from motor vehicles on roads with speeds above 30 km/h (notably footpaths) and those that enable pedestrians to cross roads safely and arterial roads in particular, are also important mechanisms to ensure safety.

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Police and TAC Data

Data was extracted from the Victoria Police Accident Records System (VPARS) linked to the TAC claims dataset, for pedestrian crashes between 2009 and 2018 and compared against hospitalised data. It should be noted that not all crashes involving injury to pedestrians require hospitalisation and/or police attendance; so there are some differences between data collected in each data set. In addition, not all pedestrian injuries occurring on a road or roadside involve vehicles and as such are not included in VPARS or TAC data. Furthermore, there is only limited information in the data regarding the circumstances that may have contributed to the collision. This reflects the limitations of the codes used to classify pedestrian crashes.

Across the period, cars were involved in 17.9 pedestrian crashes for every 100,000 registered vehicles in Victoria. By comparison, the crash rates for taxis (728.3), panel vans (204.5) motor scooter or moped (154.7) and buses (99.0) were all much higher.

Police reported the driver involved in the crash as offending in 46.4 percent of collisions, while 35.5 percent were not considered as offending and for 18.1 percent this was not known or reported. A concerning finding was that 15 percent of all pedestrian crashes were coded as Hit/Run.

Analysis of vehicle movement indicates that the highest proportion of collisions involved a vehicle travelling straight ahead (43.5%), followed by right (15.7%) and left turning (8.5%) vehicle movements and reversing (6.7%).

There was a similar proportion of collisions at, and away from, intersections. The majority of pedestrian crashes were found to occur on roads with posted speed limits of 60 km/h (31.0%) or 50 km/h (29.8%). Fatal and serious injuries were more likely on roads with higher speed limits.

The majority of crashes were reported within the Metropolitan Melbourne area (81.5%), however rural and regional Victoria were over-represented when considering population statistics.

The highest concentration of crashes occurred in the Melbourne CBD, from Southbank to Carlton, reflecting high pedestrian activity. Other sizeable clusters included St Kilda, Prahran, Footscray, Preston, Dandenong, Frankston, Geelong and Werribee. There were also less prominent clusters at many major intersections, particularly along major arterial corridors, and in the vicinity of railway stations.

The highest proportion of pedestrian crashes occurred in the afternoon, between 2:00pm and 3:59pm (14.4%) and 4:00pm to 5:59pm (14.3%), with a more defined morning peak between 8:00am and 9:59am (12.0 %). Young people (16-39), especially males, were over-represented in collisions that occurred at night, most notably between 10:00pm and 6:00 am. Previous research has identified these as high alcohol times.

When considering the month of the year, crash rates were higher in the winter months. While this may indicate an increased risk for pedestrians when it is dark or wet, across the year the majority of pedestrian collisions occurred in clear weather conditions (82.4%, compared to rain 9.3%) and during daylight hours (63.6%). The proportion of crashes occurring when it was dark was 27.6 percent (mostly where street lights were on) and 6.8 percent of crashes occurred at dusk or dawn.

Hospital Data

Separate datasets were analysed for both hospital admissions and Emergency Department (ED) presentations, for all pedestrian cases between 2008 and 2017, which was the most current data available.

There were at least 10,845 hospital admissions and 11,590 emergency department presentations involving an injured pedestrian during this period – averaging more than 2,200 per annum.

When considering the types of injuries sustained, the most commonly injured body region was the head, followed by injuries to the knee, lower leg and foot. Across the two datasets, fractures were the most common type of injury, representing 21.3 percent of cases to the ED and 44.5 percent of hospital admissions.

Half of hospital admissions were less than 2 days in duration, but 32.5% were for 2-7 days, 14.8% were stays of 8-30 days and 1.9% of hospitalisations extended for more than a month.

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General Findings

In addition to analysis of the datasets above, pedestrian deaths in Victoria between 2008 and 2017 were extracted from the National Cause of Death Unit Record File. This recorded an average of 56.4 fatal pedestrian injuries recorded per annum in Victoria. The majority of pedestrians were killed due to being hit by a car (68.4%), followed by heavy transport vehicles or buses (13.1%) and trains (9.2%).

In terms of trends, the number of crashes involving a pedestrian that were reported to police decreased by 3.3 percent per annum, from 1,740 reported crashes in 2009 to 1,320 reported crashes in 2018. However, the decrease occurred mainly in the first half of the study period and the level of reported crashes remained reasonably constant over the final 5 years. The hospital data, which captures a higher proportion of pedestrian crashes, shows a slightly different picture. The emergency department presentations only decreased by 1.54%, and there was no real change in the rate of hospital admissions. The general trend in fatalities is downward, but with considerable variation between years.

When considering Victoria's rapidly increasing population, the relative risk to pedestrians when walking is decreasing. Time trend analysis suggests that the risk of pedestrian injury at a population level is reducing across gender and age groups, although the lowest rates of reduction were observed for older pedestrians, when considering population as an exposure measure.

It should be noted that the detailed datasets analysed in this report do not encompass the increase in pedestrian fatalities in 2019.

In general, males were found to have a higher risk of injury compared with females, although in some instances the differences were not statistically significant. The notable over-representation is in fatalities, where men are almost twice as likely to be killed as pedestrians compared to women.

When considering age groups, compared to pedestrians aged between 16 and 39 years, children (0 to 15yrs) had roughly half the risk of crash involvement when controlling for population. Adults aged 40 to 59 years had lower relative risks of injury.

Pedestrians aged 70 years and older have the greatest risk of injury, roughly 1.6 times higher than young adults (16 to 39 years). In police data adults aged 70 years and older were 15 percent of all injury cases, while only 10.7 percent of the Victorian population.

Executive Summary

Recommendations

The following recommendations are made to reduce on-road pedestrian deaths and serious injuries.

Safer speeds and safer roads

Recommendations include:

- Reductions in speed limits, including to 30 km/h in areas of high pedestrian activity and residential streets;
- Speed limit reductions are supported with appropriate traffic calming infrastructure to ensure drivers and riders are compliant with speed limits;
- Provision of more pedestrian oriented developments (pedestrian prioritisation);
- Implementation of Safe System aligned treatments to separate vulnerable road users and vehicles and create safer crossing points;
- Implementation of Safe System aligned treatments to improve sight distance and visibility of pedestrians;
- Provision of safe, convenient and direct walking routes to minimise the need for risky walking behaviours; and
- An ongoing program of state government investment to deliver these improvements.

Safer vehicles

Recommendations include:

- Development of programs and initiatives to address improved uptake and awareness of safer vehicles (e.g., targeted education campaign on safe vehicle purchase and use; providing financial or other incentives for purchasing safer vehicles);
- Enhance and further promote existing information and resources such as www.howsafeisyourcar.com.au, www.ancap.com.au, used car safety rating guides; and
- Further development of technologies to assist with detection of pedestrians and crash avoidance.

Safer road users

Recommendations include:

- For drivers, develop educational and training programs addressing pedestrian safety and adoption of safer driving practices and enforcement of lawful driving;
- Support national efforts to promote walking and walkable communities through health promotion campaigns;
- For older pedestrians, development and implementation of education and behavioural programs providing information on schemes and initiatives to support and promote active travel, technologies and other media to provide active travel information;
- For children, development and implementation of educational and training programs promoting safe active travel co-ordination with schools, parents and councils to provide safety around school environments; and
- For young adults, development of programs addressing alcohol and drug use and walking, alongside measures to manage the road environment around alcohol venues.

Introduction

Walking is the most fundamental mode of transportation. In essence all road users are pedestrians, with walking forming part of almost all trips (Cassell et al. 2010, Devlin et al. 2010). The walkability of a city is intrinsically linked to liveability, as walking provides health, fitness, exercise, enjoyment, a sense of freedom, well-being and relaxation (Forward 1998, Hydén et al. 1998, Oxley et al. 2005). Walking also promotes social inclusion and equity within a community (Methorst et al. 2010). Furthermore, walking is the most environmentally sustainable mode of transportation and there are a broad range of social, environmental and economic benefits associated with the physical exercise gained through walking, particularly when walking trips are made instead of private motorised travel (Cassell et al. 2010).

While the benefits of increasing the number of walking trips are well established (WHO 2007), pedestrians are one of the most vulnerable road user groups, due to their lack of physical protection and limited capacity to withstand biomechanical forces (Oxley et al. 2004, Oxley et al. 2011, Palamara & Broughton 2013), particularly when involved in collisions with motor vehicles travelling at speeds higher than 30-40 km/h. Estimates suggest that pedestrians are approximately four times more likely to be injured in traffic crashes compared to other road user groups per kilometre travelled (Elvik 2009).

According to the World Health Organisation, globally there are approximately 1.35 million road traffic deaths per year and approximately 23 percent of these deaths are pedestrians (WHO 2018). In Australia, Victoria has the second highest rate per population of pedestrian injuries, compared to other States and Territories. Previous analyses have found that approximately ten percent of all police-reported serious injury and fatal crashes involve injured pedestrians (Cassell et al. 2010). Furthermore, it has been established that children, the elderly and the intoxicated are typically the most vulnerable sub-groups of pedestrians (Oxley et al. 2013) and are disproportionately over-represented in injury statistics.

To date a large proportion of pedestrian-based road safety research conducted in Victoria has tended to focus on data reported in police report crash datasets, with a small selection of studies considering hospital reported cases. However, few studies have considered pedestrian trauma across a broader spectrum of injury severity. Furthermore, the majority of pedestrian road safety research has focused on analysis of incidence and has not considered exposure measures in order to identify injury risk.

To address the limitations associated with previous pedestrian research, Victoria Walks, in conjunction with the Monash University Accident Research Centre (MUARC), with support from the Transport Accident Commission (TAC) Community Grants Scheme 2019, have undertaken this ecological study of pedestrian collisions in Victoria, Australia.

1.1 Aim

The aim of this project is to conduct an ecological study investigating the rates of pedestrian trauma in Victoria. Analyses of multiple injury register datasets were undertaken to develop a comprehensive understanding of the issues and factors associated with pedestrian injury across all levels of trauma, with a particular focus on injury resulting from collisions with other road user types.

To complement the analyses a review of the literature was conducted focusing on pedestrian road trauma in Victoria. The aim of the review was to consolidate previous research and understand key issues that have previously been identified including; injury severity, subgroups of pedestrians, crash locations, injury mechanisms, collision counterparts, injury outcomes and pedestrian exposure. Furthermore, the review was conducted to provide an understanding of the current state of knowledge regarding effective countermeasures to reduce pedestrian trauma.

The report concludes with a discussion of the key findings from the literature and the injury analyses and provides a set of recommendations for interventions and further research to reduce pedestrian trauma in Victoria.

2 Literature Review

A targeted literature review was undertaken to gain a stronger understanding of previous pedestrian injury research. The literature review was specifically focused on previous research undertaken in Victoria, however, consideration was given to interstate and international literature, particularly when identifying evidence-based countermeasures.

An extensive range of search engines and databases, available through Monash University library services, were utilised to source relevant published scientific literature.

The search covered the ten-year period 2011-2020 and the following databases were accessed:

- Google scholar
- TRID
- Science Direct
- Web of Science
- PsychInfo.

Key words included: 'pedestrian' 'road safety', 'injury', 'injury severity', 'countermeasure', 'evaluation', and 'Victoria'.

2.1 Background

Walking has numerous benefits to individuals and to the broad community, as it can increase fitness, health and longevity for people of all ages. Walking is the original, fundamental mode of movement that is healthy, sustainable, environmentally-friendly, is also space-efficient and causes negligible harm to others. Leading a physically active life assists individuals by reducing risk of developing health complications but also can increase cognitive function and slow down functional and mobility decline. For older adults, especially, walking is particularly important for healthy ageing, physical activity, exercise, recreation and social/economic connectedness (Zuckerman et al. 1993, Garrard 2013, WHO 2015, Badawi 2018). Furthermore, environmental, social and economic benefits arise for people, as it can alleviate issues related to motorised travel such as pollution, congestion and the increasing costs associated with maintaining a vehicle and road infrastructure (Ogilvie et al. 2004, Devlin et al. 2012). Walking supports and links intrinsically to public transport, particularly trams and Light Rail Vehicles (LRVs), buses and rail, which are also to be encouraged because of their greater efficiency, support for healthy, active travel and long-term sustainability. These attributes are especially important for large and growing cities (Corben 2020).

However, pedestrians are considered vulnerable road users largely due to their lack of protection and limited biomechanical tolerance to violent forces if hit by a motor vehicle. In a collision with a vehicle, pedestrians are always the weakest party and are at a greater risk of injury or death compared with other road users (Oxley et al. 2013).

Literature Review

2.2 Contributing Factors

There is an extensive body of literature addressing and documenting the key risks to pedestrians, and the contributing factors. These include issues related to a broad range of factors, including: infrastructure in terms of a lack of dedicated facilities for pedestrians such as footpaths, crossings and raised medians; pedestrian characteristics and behaviour; driver behaviour, particularly in relation to, speeding, failing to give way, distraction, as well as drinking and driving; and vehicle design in terms of solid vehicle fronts that are not forgiving to pedestrians should they be struck. Crashes are complex and involve multiple contributing factors, and much of the literature attests to the interrelations between contributing factors (e.g., (WHO 2013, Dong et al. 2019, Thomas et al. 2019). As an example, Dong and colleagues' modelling of factors associated with injury severity as a result of a collision with a vehicle suggested that pedestrian characteristics included age and alcohol (high BAC level), driver characteristics included drink driving, previous recorded crashes and number of occupants, vehicle factors included vehicle body type, model year and travel speed, and roadway/ environmental characteristics included roadway profile, intersections, light and weather conditions.

2.2.1 Road Environment and Vehicle Speed

There is a close association between the walking environment and pedestrian safety. The safety of pedestrians is compromised to a large extent by the design and operation of the road-transport system, which is generally designed for vehicles and, for the most part, seems to be unforgiving for the most vulnerable road users. Walking in an environment that lacks pedestrian infrastructure and that permits use of high-speed vehicles increases the risk of pedestrian injury. The risk of a motor vehicle colliding with a pedestrian increases in proportion to the number of motor vehicles interacting with pedestrians (WHO 2013). Pedestrian injuries generally occur more in urban areas compared with rural settings, particularly in high income countries. In the US, Nesoff et al. (2018) noted that approximately 80 percent of pedestrian fatalities occur in urban environments. This is not surprising given high traffic flow and population densities in urban areas. Arterial roads have long been identified as being problematic for pedestrians (e.g. (Zegeer et al. 2010, Turner et al. 2017, Corben 2020), predominantly as they are typically multi-lane roads with higher speeds and traffic volumes. In these environments there are often different types of road users mixing and interacting within limited road space. These road users include cars, pedestrians, cyclists, motorcyclists, commercial vehicles, buses, and other forms of public transport.

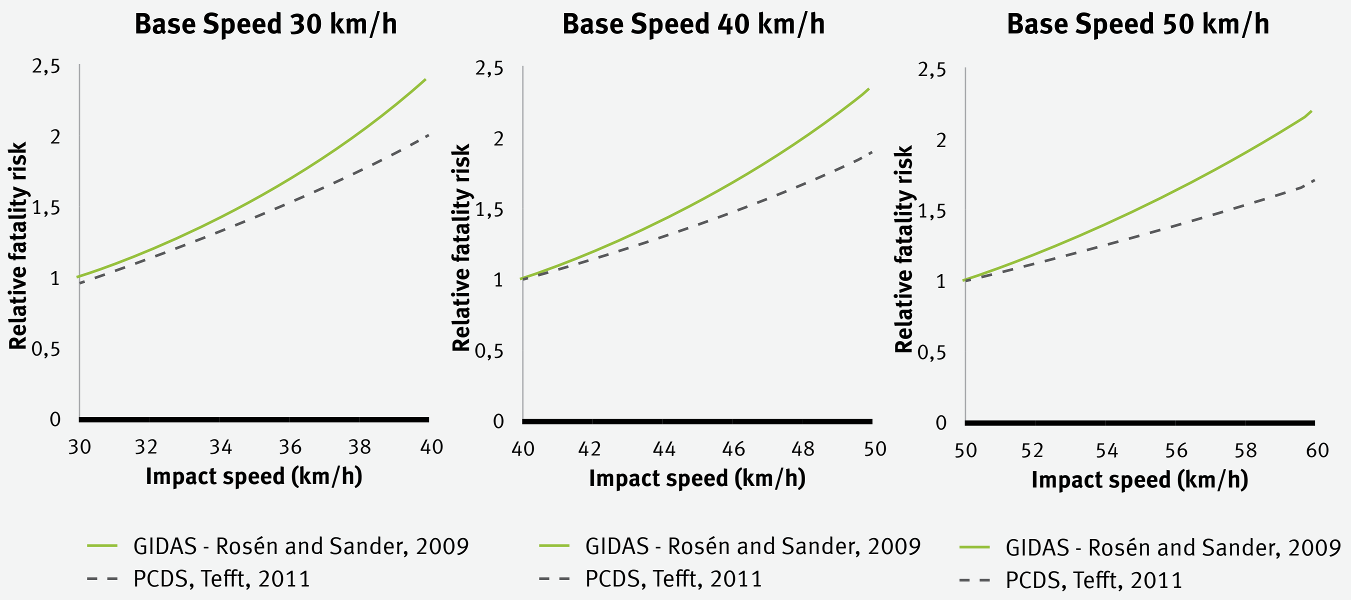
2.2.1.1 Speed and speeding

Speed and speeding has a great impact on pedestrian safety and there have been calls over many years for moderating vehicle speeds of drivers in high activity pedestrian areas (Job 1994). The relationship between impact speed and risk of fatality is strong and should be a critical factor in making decisions regarding the setting of speed limits and designing roads to reduce vehicle speeds, particularly in environments where there is a mix of vehicles and vulnerable road users (Rosén et al. 2011, Kröyer et al. 2014). The evidence shows that the higher the travel speed of a vehicle, the higher the impact speed will be, and the probability of injury, and the severity of injuries that occur in a crash, increases, not linearly, but exponentially with vehicle speed – to a power of four for fatalities, three for serious injuries and two for casualties. Even small increases in speed can result in a dramatic increase in the impact forces experienced by crash victims.

It is estimated that, for every 1 km/h increase in mean speed, the number of injury crashes will rise by around 3 percent (thus an increase of 10 km/h would result in a 30 percent increase in injury crashes) (Nilsson 1984, Tefft 2013).

One of the most recent studies estimates that the fatality risk is about 4-5 times higher in collisions between a car and a pedestrian at 50 km/h compared to the same type of collisions at 30 km/h (see Figure 1, cited in report by the International Transport Forum, 2018, https://www.itf-oecd.org/speed-crash-risk).

Figure 1: Pedestrian fatality risk and impact speed



Source: Kröyer, Jonsson, and Várhelyi (2014)

Literature Review

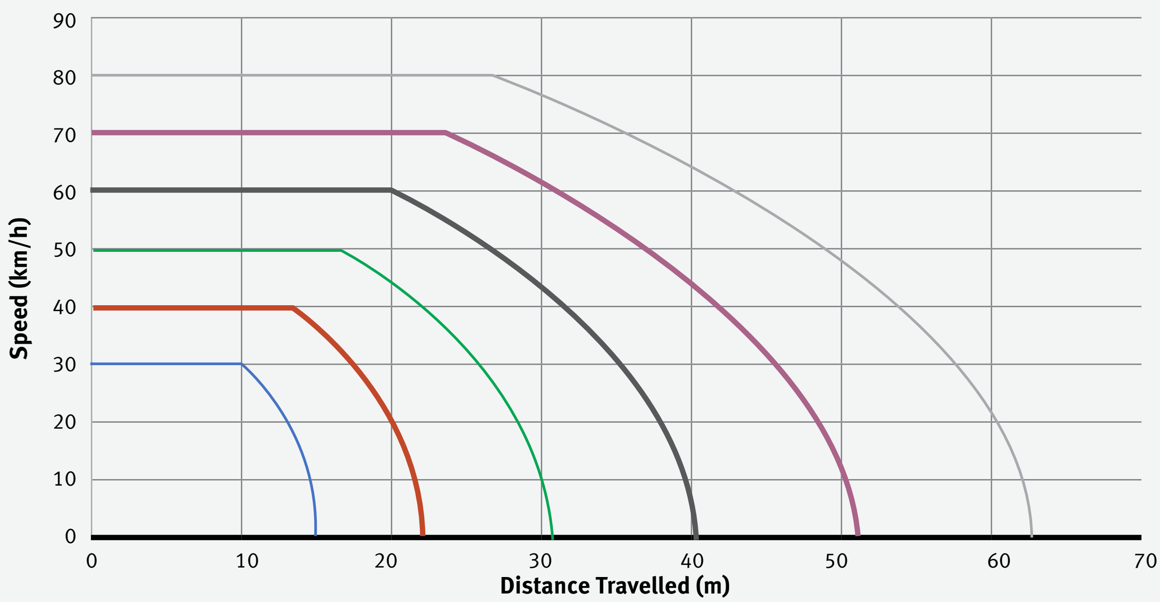
The above risk curves only account for fatalities and do not address the effects of age on injury risk. In their review of the main studies on the probability of a fatality as a function of impact speed, Logan, Corben and Lawrence (2019), favoured the use of risk curves for fatal and combined fatal/serious injury for impact less than or equal to 70 km/h (after Davis (2001), while also acknowledging the methodological shortcomings of past studies. Logan and colleagues noted that, at impact speeds of 30 km/h:

- the risk of a fatality or serious injury is around 25% for pedestrians aged up to 60 years; and
- the risk of a fatality or serious injury is around 70% for pedestrians aged 60+ years.

While the evidence on the effect of impact speed on pedestrian injury risk is strong, the effect of vehicle speed on crash risk is less clear. Traditionally, speed as a risk factor has been viewed primarily in terms of its effect on vehicle stopping distances. Higher speed also increases the distance a vehicle travels while the driver reacts to a potential collision, reducing the time available to avoid a collision (Dumbaugh & Li 2011, Corben 2020). The stopping distance of a vehicle comprises two main components:

- Perception-reaction time/distance – the distance travelled by a vehicle while the driver perceives the need to stop and then to react by activating the brakes. Typical durations for drivers are in the order of 1.2 to 1.5 seconds, but can be considerably longer for drivers who are distracted, inattentive, drowsy, slowed by age or otherwise performing below population averages; and
- Braking distance – the distance required by a vehicle to come to a stop, from the point where the brakes were applied. These distances are determined by physics, and in particular the initial speed of the vehicle. The higher the speed of a vehicle, the shorter the time a driver has to stop and avoid a crash, including hitting a pedestrian.

Figure 2: Stopping distances of typical passenger cars for a range of initial travel speeds (calculations assume a coefficient of friction of 0.70 and a driver perception-reaction time of 1.2 seconds) (Corben 2020)



Literature Review

In addition, the quantity of information to be processed by a driver increases significantly as vehicle speed increases. Given the limitations of cognitive, attentional and visual systems, these can be overloaded when driving at high speed and can result in reduced predictability, reduced ability to control the vehicle, and reduced ability to detect, negotiate and maneuver around obstacles on the roadway (Wolfe et al. 2017).

Speed limits, and their relationship to road trauma, have been broadly researched. This has usually been undertaken by examining the effect of a change in speed limit (e.g., Farmer (2017), Hoareau et al. (2006), Vadeby & Forsman (2013), Nishimoto et al. (2019) and Mackenzie et al. (2015).The clear majority of these types of studies found that when speed limits were increased, injury crashes also increased and that when speed limits were decreased, injury crashes also decreased. This prior research has led to the general conclusion that lowering speed limits reduces the severity of crashes. Some Australian examples include:

- Doecke et al. (2018) examined the relationship between speed limit and injury severity for different crash types, using police-reported crash data in order to provide empirical evidence for safe speed limits that will meet the objectives of the Safe System. A positive exponential relationship between speed limit and fatality rate was found. For an example fatality rate threshold of 1 in 100 crashes it was found that safe speed limits are 40 km/h for pedestrian crashes; and
- In Victoria the default speed limits were reduced from 60 km/h to 50 km/h in built up areas in 2001. Hoareau et al. (2006) conducted an evaluation of the change in default speed limits and estimated that fatal and serious injury crashes involving pedestrians were reduced by 25 to 40%.

This evidence clearly shows that pedestrians are only safe mixing with traffic travelling at 30-40 km/h and has been instrumental in promoting lowered speed limits and supporting traffic calming in built up areas (strip shopping centres, residential streets, etc.). However, there remains some contention among researchers about whether 30 km/h accurately defines the boundary condition for Safe System risk levels. The contention centres largely on experimental methods used in collecting data on crashes and the potential for bias in sampling. Numerous research studies have been undertaken on this topic and, while each has strengths and weaknesses, overall there is a lack of clear and precise consensus. Jurewicz et al. (2016) present risk curves that suggest pedestrian-vehicle impact speeds of around 20 km/h should not be exceeded if Safe System criteria are to be met. This is based on the following criteria:

- injury severity, given a crash, is proportional to impact speed;
- crash likelihood affected by road geometry and road user behaviour; and
- exposure to crash risk is proportional to average traffic flows.

2.2.1.2 Road design

Pedestrian risk is increased when roadway design and land-use planning fail to plan for and provide facilities such as footpaths, or adequate consideration of pedestrian access at intersections (Sleet et al. 2011, WHO 2013). Infrastructure facilities and traffic control mechanisms that separate pedestrians from motor vehicles and enable pedestrians to cross roads safely are important mechanisms to ensure pedestrian safety, complementing vehicle speed and road system management (Zegeer et al. 2010, Sleet et al. 2011, WHO 2013, Hu & Cicchino 2018).

Stephan (2015) investigated the factors influencing crash risk on arterial strip shopping centre road segments in Melbourne and found that the design of the road, roadside, traffic volumes and the facilities and amenities in the surrounding environment were associated with crash risk. The effect of some risk factors differed by crash type. Wider carriageways were associated with reductions in multi-vehicle crashes (MVC) and single-vehicle crashes (SVC), however, they were also associated with increases in pedestrian-vehicle crashes. The presence of off-street parking facilities was also associated with reductions in MVC and SVC, but increases in crashes involving pedestrians. It is therefore essential to consider the effect of changes in road design and operational objectives on the safety of all road users. Other risk factors had a consistent effect across crash types. As the number of unsignalised intersections per km increased, so did the incidence of MVC and crashes involving pedestrians.

The presence of roadside parking on both sides of the road increased the risk of an MVC, while the presence of parking clearways was associated with reductions in pedestrian-vehicle crashes. Situations of potential conflict are therefore a concern for all road users. Reductions in the speed limit appear to be of particular benefit to vulnerable road users in strip shopping zones. The incidence of pedestrian-vehicle crashes was reduced on roads with a permanent 40 or 50 km/h speed limit, in comparison to roads with a 60 km/h speed limit.

Mansfield et al. (2018) explored associations between transportation system and built environment characteristics and pedestrian fatalities between 2012 and 2016 at the Census tract scale across the United States. They noted that traffic on certain roadway facility types and employment in certain sectors have especially strong associations with pedestrian fatality risk. Specifically, in urban tracts, strong associations were found between traffic on non-access-controlled principal arterial and minor arterial roadways and pedestrian fatalities (0.91 and 0.68 additional annual pedestrian fatalities per 100,000 persons per 10,000 VMT/mi2 increase in traffic density, respectively). In both urban and rural tracts, they also found strong associations between employment density in the retail sector and pedestrian fatalities.

Hu & Cicchino (2018) examined pedestrian fatalities in the US by roadway, environmental, personal and vehicle factors between 2009 and 2016. They noted that the largest increases in pedestrian deaths during this period occurred in urban areas (54% increase), on arterials (67% increase), at non-intersections (50% increase), and in dark conditions (56% increase).

Olszewski et al. (2019) examined factors affecting fatality risk of pedestrians, cyclists, motorcyclists, and moped riders in seven EU countries using the CARE database (the European centralised database on road accidents), with a focus on identification of road infrastructure-related conditions and factors that have a negative impact on vulnerable road user traffic safety. Between 2009 and 2013 pedestrians comprised most fatalities (47%), followed by motorcyclists (28%), cyclists (19%), and moped riders (6%). The effect of darkness on fatality risk was negative for all categories of vulnerable road users, however, on average, the strongest effect was clearly for pedestrians. This is consistent with the findings of other studies (Johansson et al. 2009, Gaca & Kiec 2013) and confirms the importance of good lighting of intersections and road segments in general and especially those heavily used by pedestrians.

In addition, there is evidence that injury risk is associated with poor visibility of pedestrians. Inadequate visibility of pedestrians arises from:

- inadequate, or lack of, roadway lighting;
- vehicles and bicycles not equipped with lights; and
- pedestrians sharing road space with fast-moving vehicles.

2.2.2 Pedestrian Characteristics and Behaviour

Statistics and research alike suggest that older adults, children and the intoxicated are at highest risk of a pedestrian collision, and that injury severity increases as age increases. There are additional emerging potential risk factors including distraction.

Chong et al. (2018) reported 47,789 deaths and 674,414 injuries from pedestrian–motor vehicle collisions in the U.S. from 2006 to 2015. Over this time, there was a significant increase in fatalities within a number of US States. Fatality rates were consistently high among the elderly, whereas injury rates were highest in adolescents and young adults. Factors associated with increased risk of pedestrian death after a motor vehicle collision included male sex, aged 65 years or older, pedestrian or driver alcohol use, the collision occurring during overnight hours (i.e., midnight to 5:59AM) at non-intersections, and if the collision involved a heavy vehicle.

2.2.2.1 Children

Young children's safety as pedestrians is of particular concern in view of their vulnerability in traffic situations and the special value society places on children (Oxley 2005, Morrongiello & Barton 2009). Young children are particularly vulnerable as pedestrians for a number of reasons, including:

- They are immature and have less developed cognitive, attentional, perceptual and visual skills than older children;
- They are more likely to be distracted by irrelevant information and experience more difficulty controlling impulsive reactions compared with older children and adult pedestrians;
- They are inexperienced in traffic and are unable to independently make safe judgements concerning the speed and distance, and therefore time of arrival of approaching traffic when crossing vehicle paths. This ability to recognise and respond safely to traffic hazards remains under-developed, for the most part, throughout their primary school years;
- They experience difficulty choosing a safe crossing location (often involved in 'dart out' collisions from in between parked vehicles);
- They are less confident in traffic;
- They are small in stature and, therefore, have greater difficulty seeing hazards in traffic and being seen by motorists; and
- Because of their small stature, in a crash they are more likely to be struck in the head or upper body, both areas having an elevated risk of producing severe injury. Additionally, their size makes them more likely to be driven over in a vehicle impact. Thus, even at low impact speeds, when the risk of serious injury is relatively low for pedestrians in general, injury risks to young children remains high due to their greater susceptibility to being run over by an impacting vehicle (Whitebread & Neilson 2000, Zeedyk et al. 2002, Sarkar et al. 2003, Tabibi & Pfeffer 2003, Barton et al. 2007, Christie et al. 2007).

There is evidence that children aged below 10 years, have relatively poor skills at reliably setting safe distance gap thresholds, and thus do not consistently make safe crossing decisions (Connelly et al. 1998). It has been suggested that children's poor skills at selecting appropriate gaps in traffic are due to the fact that distance, rather than an approaching vehicles speed, is a primary factor in determining gap acceptance thresholds (Connelly et al. 1996, Connelly et al. 1998, Simpson et al. 2003)

2.2.2.2 Older adults

Older adults are over-represented in pedestrian fatalities and are at an increased risk of severe injury due to their frailty compared to young adults. Older adults are more likely to sustain fractures to all body parts in a crash, their recovery time is high, and the likelihood of long-term disability is high. A large component of the literature on older road users is concerned with the consequences of ageing on sensory, visual, perceptual and cognitive abilities. Inadequate functioning in any of these areas can reduce performance and increase risk on the road. While onset of age-related changes can affect many areas of daily living, it is important to recognise that older road users are generally safe and cautious. Indeed, there is good evidence to suggest that older road users in Australia self-regulate their travel patterns by adopting cautious behaviours (Charlton et al. 2006). Older pedestrians, too, appear to adopt self-regulatory and cautious behaviours while crossing the road (Oxley et al. 1997).

However, it may be that a number of older road users are less able to compensate for age-related changes and therefore may be at an increased risk. When demands are significantly complex, in situations such as selecting safe gaps in the traffic, some older pedestrians may experience difficulties. A large body of literature suggests that some older adults make risky crossing decisions and experience difficulties selecting safe gaps in order to accommodate their slower walking speeds and are less confident on the streets (Dommes & Cavallo 2011, Dunbar 2012, Zhuang & Wu 2012, Dommes et al. 2015, Kim 2019)

2.2.2.3 Intoxicated pedestrians

A substantial proportion of pedestrian deaths and serious injuries involve intoxicated pedestrians. According to the Transport Accident Commission (2009), in Victoria 30 percent of all pedestrians involved in a fatal collision in 2008 had a BAC of at least 0.05g/100ml, and the risk of a fatal outcome increased as BAC level increased.

An investigation of pedestrian deaths showed that almost half the pedestrians killed in Australia (45%) were walking while intoxicated (ATSB 2001), and approximately 1 in 3 had a BAC exceeding 0.08 to 0.1 g/dl. (Cairney et al. 2004). More recent data from Queensland indicates that this situation has not changed (TMR, 2012). Based on Queensland statistics of injured 'drink walkers', the following pedestrian groups are at heightened risk of being killed or seriously injured whilst 'drink walking':

- Males (in 2011, 66.7% were male);
- 30-39 year olds (in 2011, 33.3% were aged in their thirties);
- Younger persons (in 2011, 26.7% were aged 17-20 years), often due to their heightened risk of binge drinking engagement in drink walking (Haque et al. 2012) ; and
- Indigenous pedestrians. Pedestrian casualties show a disproportionate number of Indigenous people, and Indigenous pedestrians that are struck by a vehicle often have high BAC's. For the 2001/02 to 2005/06 Queensland data period, of the 175 Indigenous people killed or hospitalised as a pedestrian, 53.7% were under the influence of alcohol (compared to 20.2% of the non-Indigenous people killed or hospitalised as a pedestrian) (TMR, 2012).

Eichelberger et al. (2018) investigated the prevalence, trends, and characteristics of alcohol-impaired fatally injured pedestrians and bicyclists in the US. Data from the Fatality Analysis Reporting System (FARS) were analysed for fatally injured passenger vehicle drivers, pedestrians, and bicyclists 16 and older during 1982–2014. Logistic regression models examined whether personal, roadway, and crash characteristics were associated with high blood alcohol concentrations (BACs) among fatally injured pedestrians and bicyclists. During this period, the proportion of fatally injured pedestrians with high BACs (≥0.08 g/dL) declined from 45 to 35 percent. The largest reductions in alcohol impairment among fatally injured pedestrians and bicyclists were found among ages 16–20. During 2010–2014, fatally injured pedestrians and bicyclists aged 40–49 had the highest odds of having a high BAC, compared with other age groups.

In contrast, Hezaveh & Cherry (2018) identified crashes between motor vehicles and pedestrians who were walking while alcohol-impaired in Tennessee. Results indicate that the number of fatally injured alcohol-impaired pedestrians has increased since 2011. Alcohol was present in 7 percent of the pedestrian crashes. Tested pedestrians averaged BAC levels of 0.17 g/dL. As pedestrian injury severity increased, the share of the alcohol-impaired crashes increased. Analysis also revealed that 83 percent of the alcohol-impaired crashes occurred during the night; moreover 54 percent of crashes occurred on weekends, 69 percent at a mid-block section of the road, and 85 percent at areas with no traffic control device. Results of a binary logit regression indicate that pedestrian's age, males, posted speed limit, and night-time crashes had a positive association with the crashes. On the other hand, urban context, intersection crashes, driver manoeuvres (i.e., parking-related, turning, and straight), and daylight had a negative association with the WUI crashes.

Öström & Eriksson (2001) also stated that intoxicated pedestrians suffered more head injuries compared to non-intoxicated pedestrians. Dultz & Frangos (2013) confirmed that intoxicated pedestrians usually sustain more severe injuries, which required longer duration hospital stays.

Given the overwhelming evidence of alcohol impairment on many tasks, particularly driving (Lenne et al. 1999), it is entirely possible that decreased cognitive functioning and inhibition would effect judgement and performance when crossing roads. Unfortunately, there are few studies exploring the effect of alcohol impairment on pedestrian performance. In a simulated road-crossing study, adults with BACs of 0.07–0.10 g/dL had difficulty integrating speed and distance information when selecting gaps in traffic compared with controls who did not ingest alcohol (Oxley et al. 2006). Dultz et al. (2011) found that among crash-involved pedestrians treated at a trauma center, those who had been drinking were more likely at the time of the crash to have crossed the road at a dangerous location, such as at an intersection against the traffic signal or midblock without a traffic signal, than pedestrians who had not been drinking.

2.2.2.4 Distraction

The nature of driver distraction has been well documented in research over recent years (e.g. Klauer et al. (2006); Brodsky (2018); however, less is known about the occurrence of pedestrian distraction. The number and complexity of potentially distracting technologies used by pedestrians (e.g. smartphones) is likely to further rise over the next decade and, as a road user group, pedestrians are particularly vulnerable to being fatally or seriously injured in collisions with other road users.

A number of studies suggest that device use while walking is common, and that their use can affect behaviour and performance. An experimental study demonstrated that mobile phone users walked more slowly, changed direction more often and had poorer observational skills than other walkers, including those using a music player (Hyman et al. 2010).

A systematic review of studies to evaluate increased risk for crashes/near-crashes for youth pedestrians, cyclists and drivers while distracted was recently undertaken by Stavrinos et al. (2018). The findings related to pedestrian distraction were as follows: the 5 distracted walking studies utilized either experimental designs with virtual reality pedestrian environments (Stavrinos et al. 2009, Chaddock et al. 2012, Byington & Schwebel 2013, Parr et al. 2014) observational strategies (Thompson et al. 2013). Developmental differences were minimal: Mobile technology use impaired pedestrians' visual attention to traffic in children ages 10–11 (Stavrinos et al. 2009) as well as emerging adults (Byington & Schwebel 2013, Thompson et al. 2013). When distracted by visually demanding tasks (e.g., texting), pedestrians waited longer, missed more opportunities to cross safely (Byington & Schwebel 2013), and crossed more slowly (Parr et al. 2014). Step width, toe clearance, step length and cadence also diminished while texting (Parr et al. 2014). In observational field research, texting pedestrians were more likely to cross unsafely (Thompson et al. 2013). When distracted cognitively but not visually demanding tasks (e.g., phone call), pedestrians waited significantly longer to cross, missed more opportunities to cross safely (Stavrinos et al. 2009), and crossed more slowly (Thompson et al. 2013).

A recent observational study of pedestrians crossing roads at eight city sites in Melbourne, Australia during daytime conditions (Horberry et al. 2019) revealed that, on average, 20 percent of pedestrians were using their smartphones when crossing roads, significantly more critical events occurred with smartphone users compared to non-smartphone users, and that the pattern of critical events was different for smartphone and non-smartphone users.

Other studies suggest similar use of devices while walking. For example, Williamson & Lennon (2015) undertook intercept interviews among pedestrians in New South Wales and found self-reported frequency of smartphone use for potentially distracting activities whilst walking or crossing a road was high, especially among 18–30 year-olds. Thirty percent of this age group indicated they engaged in texting or accessed the internet on their smartphones at least once a week whilst crossing the road.

Moreover, the naturalistic observational literature typically suggests a range of unsafe behaviours: smartphone-distracted pedestrians were less likely to wait for the crossing light, to look left and right before crossing the street or to make eye contact with approaching drivers (Basch et al. (2014), Brumfield & Pulugurtha (2011), Bungum et al. (2005), Cooper et al. (2012), Hamann et al. (2017), Thomas et al. (2013), cited in Horberry et al. (2019).

While the evidence suggests that a small proportion of pedestrians might possibly be distracted by smart phone use while crossing the street, we are not aware of any studies that have established a significant connection between pedestrian smart phone use and actual crashes.

Smart phone use by drivers is likely to be a more significant threat to pedestrian safety than smart phone use by pedestrians. For example, a study by the New York City Department of Transportation concluded, after considering both local and nation-wide data "distracted walking is a very minor contributor to pedestrian death and injury. Ultimately, interventions that lead to more responsible driving behaviour are the key to driving down fatalities throughout the city" (New York City Department of Transportation 2019).

2.2.3 Driver Characteristics and Behaviour

Driving at high speed in areas of high pedestrian activity, driving while impaired and while distracted, as well as poor attitudes to pedestrians and poor compliance have been identified as key driver-related factors that contribute to increased pedestrian risk (Summala et al. 1996, Preusser et al. 2002).

The impact of speed has been noted above, and it is also important to understand the driver factors that are associated with choosing a travel speed. Many drivers exceed the speed limits and there are a number of contributing factors that may explain why many drivers continue to drive at high speeds. Few drivers realise that risk level increases rapidly with higher speed because it is impossible to monitor these risks. Also, crash risk is seldom associated with increased speed. It is noted in the literature that speed choice is affected by a number of drivers' social and psychological factors and other characteristics (Kanellaidis et al. 2000, Oxley et al. 2004). The following factors contribute to a driver/rider's choice of speed:

- The reinforcement of habitual speeding behaviour as drivers build up a history of driving at higher speeds than the posted speed limit without crashing;
- Risk perception of risk (including perception of appropriate speed, crash risk and being caught for speeding);
- Rewarding aspects of speeding including excitement, and demonstrations of skill or courage;
- Personal characteristics such as age, gender, driving experience, risk acceptance and risk-taking behaviour;
- A driver's specific motivations associated with the trip such as immediate time savings;
- Type of road and road design features (including speed limit) and traffic condition;
- Level of alcohol or other drug impairment;
- Ownership of the vehicle; and
- Presence of passengers in the vehicle.

In addition to speed choice, distracted driving can contribute to pedestrian risk. While it is noted above that the nature of driver distraction has been well documented over recent years, little attention has been directed to the risk to pedestrians. One study was found that suggested that a possible contributor to increased pedestrian fatalities may be an increase in distracted driving because of increasing mobile phone usage. Cong and colleagues (2018) found that 44 percent of all adults report that they have been in a car when the driver used the mobile phone in a way that put themselves or others in danger. The exact effect of distracted driving on pedestrian injuries, however, is not known.

Literature Review

The most recent comprehensive systematic review of the literature on driver distraction among young drivers is provided by Stavrinos and colleagues (2018), and summarised below (all studies below cited by Stavrinos et al. (2018).

- Various methodological approaches were used, including experimental driving simulator studies, instrumented vehicles on predetermined routes, and observational/ naturalistic studies involving in-vehicle recording devices;
- Novice and experienced drivers were both impacted by mobile technology use (Schwebel et al. 2012);
- Though interacting with a phone resulted in significantly more lane deviations by teen drivers compared to older, more experienced drivers (Greenberg et al., 2003; Wikman et al., 1998), as did phone dialling (Reed-Jones et al., 2008);
- Across studies, visually demanding mobile technology tasks (texting) diverted drivers' attention from the forward roadway (Farmer, Klauer, McClafferty, & Guo, 2015a; Foss & Goodwin, 2014; Greenberg et al., 2003; Hosking, Young, & Regan, 2009; Kingery et al., 2015; Neale, Dingus, Klauer, Sudweeks, & Goodman, 2005; Wikman, Nieminen, & Summala, 1998);
- The effect of texting on response time produced mixed results, with several studies suggesting it significantly slowed driver response (Drews et al., 2009; He et al., 2015; Sawyer et al., 2014; Simons-Morton et al., 2015) and one reporting no effect (Hosking et al., 2009);
- Sending text messages led to more lane position variability and more lane excursions (Hosking et al., 2009), behaviors which were mediated by extended eye glances off the road (Kingery et al., 2015);
- Overall, speed was found to be highly variable, but significantly slower, when engaged in the visually demanding tasks associated with cell phone use while driving (Narad et al., 2013; Stavrinos et al., 2013; Farmer, Klauer, McClafferty, & Guo, 2015b), and speed increased after a call ended (Reimer, Mehler, D'Ambrosio, et al., 2010). Other research found visual phone interactions to be associated with increases in speed over short durations (Farmer et al., 2015; Reed-Jones et al., 2008). While texting, adolescent drivers' speed has been found to be either faster (Stavrinos et al., 2015) or not impacted (Reimer, Mehler, Coughlin, et al., 2010; Sawyer et al., 2014);
- Cognitively, but not visually, demanding tasks of phone conversations did not influence visual attention in naturalistic or simulated settings (Farmer et al., 2015a; Kingery et al., 2015; Kingery et al., 2015). Such cognitively-distracting tasks did, however, cause young drivers to take incorrect exits (Gaspar et al., 2014), miss turns (Kass et al., 2007) and mirror checks (Pereira et al., 2009), pause excessively at stop signs (Reimer, Mehler, Coughlin, et al., 2010; Reimer, Mehler, D'Ambrosio, et al., 2010), and proceed through yellow light indicators (Xiong et al., 2016). Conversing on phones slowed driver response time in three studies (Bellinger et al., 2009; Horberry, Anderson, Regan, Triggs, & Brown, 2006; Strayer & Drews, 2004), but not in a fourth (Narad et al., 2013); and
- A few reports of increased safety during phone conversations are published (e.g., when drivers were engaged in a hand-held phone conversation, they exhibited less variability in lane position (Tractinsky et al., 2013) and fewer lane changes (Stavrinos et al., 2013). Phone conversations also led to slower (but more variable) speed while driving (Brown, Horberry, Anderson, Regan, & Triggs, 2003; Horberry et al., 2006; Reimer, Mehler, D'Ambrosio, et al., 2010; Tractinsky et al., 2013). These safer behaviours may represent compensatory strategies.

In studies comparing visually distracting tasks to cognitive distracting tasks, texting resulted in more variability in lateral position on the roadway compared to phone conversation (Stavrinos et al., 2013, 2015), no distraction (Drews et al., 2009; He et al., 2015; Narad et al., 2013; Stavrinos et al., 2013) and using Google Glass (He et al., 2015; Sawyer et al., 2014).

Last, there is some evidence suggesting poor attitudes by drivers towards vulnerable road users. There is some evidence that the perception that vehicles have higher status on the road compared with pedestrians and consequent behaviour of drivers may contribute, in part, to increased risk of pedestrian crashes (Summala et al. 1996, Hydén et al. 1998, Preusser et al. 2002).

Literature Review

Many of the problems for pedestrians and cyclists stem from the fact that the modern traffic system is designed largely from a car-use perspective and other transport modes such as walking and cycling have a low status. Hydén et al. (1998) argued that this is primarily because of the fact that pedestrians and cyclists do not pose a threat to car occupants, therefore they are not afraid of them. The protective behavioural patterns of drivers do not therefore take enough account for unexpected and sudden movements of weaker (vulnerable) road users.

Retting et al. (1999) noted some concern that urban drivers are operating more aggressively, with less regard for traffic law and the vulnerability of other road users. Indeed, there have been many calls for moderating vehicle speeds of drivers in high activity pedestrian and cycling precincts (Job 1994, Oxley et al. 2001).

A recent study by Nesoff et al. (2018) examined knowledge, attitudes, and behaviour regarding pedestrian safety, awareness of relevant traffic safety laws, and effective strategies that could improve pedestrian safety using an online survey within a community in Maryland, US (n=3,808). They found that more drivers than pedestrians reported that pedestrian safety was an important problem (73 and 64%, respectively), a large proportion of respondents incorrectly reported the existing state laws addressing right of way, fines, and enforcement, with significant differences between drivers and pedestrians. Significantly more pedestrians than drivers supported changing traffic signals to increase crossing time, and significantly more drivers supported creating structures to prevent midblock crossing.

2.2.4 Vehicle Design

Current design of vehicle frontal structures and vehicle mass of both passenger cars and other larger vehicles contributes significantly to the severity of injuries sustained in a collision. Pedestrians struck by a car or four-wheel-drive vehicle with high bumpers and more blunt frontal profiles, are more likely to incur serious head, thoracic, abdominal and spinal injuries than when struck by a bonnet-type passenger car. In contrast, as passenger cars are becoming more aerodynamically streamlined and have lower bumpers than vans, utilities and four-wheel-drives, pedestrians struck by a newer passenger car are much more likely to incur a leg injury (Maki et al. 2003, Ballesteros et al. 2004, Lefler & Gabler 2004). Evidence suggests that children are more likely to be thrown or knocked down by light truck vehicles than passenger vehicles resulting in more serious injuries to the upper extremity and abdomen (Roudsari et al. 2005).

The relationship between vehicle type and pedestrian fatality was investigated in a study conducted by Paulozzi (2005). Paulozzi (2005) estimated that compared with passenger vehicles, the relative risk of a pedestrian fatality per mile travelled in the US in 2002 was; 7.97 for buses, 1.93 for motorcycles, 1.45 for light trucks and 0.96 for heavy trucks (Paulozzi 2005). Furthermore, pedestrian fatalities caused by a collision with a bus were more likely to involve children and adults aged above 85 years, while pedestrian fatalities caused by a motorcycle were more likely to involve children aged 0 to 14 years of age. In accordance with previous studies, Paulozzi also found a greater risk of pedestrian fatalities in urban compared to rural areas.

With the recent rise in popularity of sport utility vehicles (SUVs), minivans and four-wheel-drive vehicles in many countries, the issue of vehicle design and use of particular vehicle types is becoming more relevant to pedestrian and cyclist safety (Ballesteros et al. 2004). The typical trajectory for a person colliding with a SUV or LTV vehicle front involves initial bumper contact with the upper leg (pelvis/chest for child), above their centre of gravity; such that "wrap and carry" and rotational movement are less likely, and forward projection followed by being over-run by the vehicle is more likely (Roudsari et al. 2004, Simms & Wood 2006, Hardy et al. 2007). The head is more likely to make contact with the bonnet top (bonnet leading edge for a child) than with the windshield and at a lower impact velocity due to the reduced rotation, an event which is expected to be more pronounced in taller SUVs (Hardy et al. 2007, Kerrigan et al. 2012). Loads sustained by the pelvis are expected to be substantially higher, and contact with the stiff engine structures are expected to contribute to head injuries (Simms & Wood 2006). Furthermore, the fitting of rigid bull-bars to many large vehicles is of great concern to pedestrian safety.

In an observational study of vehicles in Adelaide, Doecke et al. (2008) reported that 45.4% of four wheel drive vehicles and 49.4% of work utilities were fitted with bull-bars. Desapriya et al. (2012) reviewed the literature addressing rigid bull bars on vulnerable road user safety and noted that vehicles fitted with bull bars, particularly those without deformable padding, concentrate crash forces over a smaller area of vulnerable road users during collisions compared to vehicles not fitted with a bull bar. Rigid bull bars, such as those made from steel or aluminium, stiffen the front end of vehicles and interfere with the vital shock absorption systems designed in vehicle fronts. The authors concluded that these devices significantly alter the collision dynamics of vehicles, resulting in an increased risk of pedestrian injury and mortality in crashes.

Most pedestrian injuries as a result of a collision with a vehicle affect the head and the lower extremities (Hu & Klinich 2015). A number of studies suggest that the design of vehicles, particularly frontal structures and their design influence pedestrian injury risk and there is evidence that particular vehicle types seem to present a higher injury risk to pedestrians (D'elia & Newstead 2015).

Fredriksson et al. (2010) examined pedestrian crash risk and injury outcomes and their relationship with vehicle design and reported the most frequent serious injury (AIS 3+) passenger car-pedestrian mechanisms: for all ages, the most frequent relationships were: leg to front end (44%), head to windscreen (25%, with 52% of these hitting impacting glass and 39% impacting the A-pillars), chest to bonnet (15%) and chest to windscreen. Also in agreement, the second most frequent mechanism was found to be different for children than for seniors and adults: head-to-bonnet occurred with greater frequency than head-to-windscreen (Roudsari et al. 2004, Fredriksson et al. 2010). The most common mechanism for fatalities was head-to windshield, followed by thorax to hood/ windshield (Fredriksson et al. 2010).

This is supported by Hu & Klinich (2015) who found that most head injuries result in damage from the bonnet (particularly among children), windshield and A-pillars, while the majority of lower limb extremities injuries are due to the front bumper. Frontal design is particularly an issue for young pedestrians as the height of, for example, an SUV results in reduced visibility of shorter pedestrians, and more severe injuries occurring to the chest and head areas. In addition to physical design, MPVs are less compliant than low profile passenger vehicles, which increases the risk of more severe injury should a pedestrian collision occur Hu & Klinich (2015).

D'elia & Newstead (2015) summarised the effects of vehicle design on pedestrian injury risk, as follows:

- increased speeds have the largest effect on torso injury severity, and the largest effect on older adults;
- at 50 km/h, lower extremity serious injuries are more likely than torso or head injuries;
- bumpers are the first impact point and cause the highest percentage of serious injuries and disability, injuring primarily the lower extremities, but may cause injuries higher up the body (femur and pelvis in adult and torso and head in children) if the vehicle is an SUV or truck, and may offer no protection if the vehicle is fitted with a bull-bar;
- bonnet surface and leading edge impacts are primarily responsible for fatal and serious adult torso and child head injuries in passenger vehicles and adult head injuries in SUVs and vans;
- torso injuries are more prevalent than head injuries when the vehicle is an SUV and the reverse is true for passenger cars;
- windshields, particularly the A-pillars are responsible for adult head injuries, which are more often fatal;
- over recent years, vehicle front geometry has become more blunt, with one cause being the increase in popularity of SUVs and utilities;
- geometry rather than mass of vehicle is the key factor explaining the injury risk differences observed for SUVs and vans when compared with passenger vehicles, however the effect of vehicle type appears only to be significant at lower speeds, whereupon speed has the most influence on pedestrian outcome;
- SUVs have a greater risk of collision with a pedestrian and a greater chance of producing a more severe injury or fatality than a passenger car; and
- vehicle design and frontal geometry contributes to the risk of a pedestrian collision through reduced pedestrian visibility.

3 Crash Data Analysis

3.1 Datasets

Analysis of various Victorian road crash, injury outcome and exposure datasets were undertaken to enhance our understanding of current pedestrian injuries in Victoria. Details of each dataset are provided in the following section.

3.1.1 Victoria Police Accident Records System (VPARS) – Transport Accident Commission (TAC) Claims Data

This dataset is an extract from the Victoria Police Accident Records System (VPARS) linked to the Transport Accident Commission (TAC) claims dataset. The VPARS dataset includes a record of all police reported casualty crashes. The linked dataset is administered by the Transport Accident Commission (TAC) and includes data on TAC claims for injury compensation from road crashes. Linked cases from the dataset were extracted for all pedestrian injuries between 2009 and 2018.

To complement the VPARS data, a summary vehicle registration data for Victoria was gathered from previously published reports. The data provides counts of the number of registered vehicles by vehicle type from 2009 to 2018 and provides an indication of pedestrian exposure to collision counterparts.

3.1.2 Victorian Injury Surveillance Unit

Injury data involving pedestrians were collected through analysis of the Victorian Injury Surveillance Unit (VISU) datasets. The VISU holds hospital-treated injury data at two levels of severity: hospital admissions and Emergency Department (ED) presentations. De-identified unit record files on Victorian hospital admissions and ED presentations are provided to VISU by the Department of Health. The VISU dataset includes both the Victorian Admitted Episodes Dataset (VAED) and the Victorian Emergency Minimum Dataset (VEMD). The VAED records all hospital admissions in public and private hospitals in the state of Victoria and the VEMD records all presentations to Victorian public hospitals with 24-hour EDs (excluding patients who are subsequently admitted to hospital). VISU data was accessed and all pedestrian cases between 2008 and 2017 were extracted for analysis, which represented the most current data available at the time of writing this report.

For cases in the VAED, the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification external cause codes (ICD-10-AM) were used to extract data (ACCD 2017). Cases were extracted from the VAED that met the following criteria:

- The external cause code was in the range V00-V09 “pedestrian injured in transport accident”;
- Principal diagnosis was a community injury (S00-T75 or T79 ICD 10 AM code); and
- Human Intent: “Non-intentional harm”

Admissions as a result of transfer from another hospital or due to a statistical separation from the same hospital were excluded. All admitted cases identified using this method of identification were included in the analysis.

The VEMD is an ongoing surveillance dataset of injury presentations to 39 Victorian public hospital emergency departments. The VEMD data is collected in accordance with National Minimum Data Standards (NMDS) for injury surveillance. While data is not coded using the ICD-10-AM system, the code set in the VEMD is similar and comparable. Cases recorded in the VEMD were extracted if the injury cause code related to pedestrians and the cases were coded as non-intentional harm. The description of event text variable was manually checked to ensure cases were relevant, cases were limited to incidence (that is return visits), and pre-arranged admissions were excluded.

3.1.3 Pedestrian Deaths Registered in Victoria

Pedestrian deaths in Victoria were extracted from the National Cause of Death Unit Record File (COD URF) for deaths registered during the period 2008 to 2017. This represented the most current data available, with finalised data available for the period of 2008 to 2015, revised data available for 2016 and only preliminary data available for 2017. As such the number of cases are likely to be revised in the future for 2016 and 2017.

For cases in the COD URF, the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification external cause codes (ICD-10-AM) were used to extract data (ACCD 2017). Deaths were extracted from the dataset that were recorded in Victoria and where the underlying cause of death was in the range V00-V09 “pedestrian injured in transport accident”.

3.1.4 Victorian Integrated Survey of Travel and Activity (VISTA)

Measures of exposure for walking were gathered through analysis of two recent VISTA household travel surveys conducted in Victoria, Australia. The surveys collected data across Melbourne, Geelong and regional centres in Victoria. Participating households were asked to complete a travel diary on a single day. Results of the surveys are weighted to represent annual travel patterns in 2009 and 2014-2016 for the broader population of Victoria. The exposure measures considered in the analysis were population, distance travelled, and number of trips.

3.2 Data Analysis

Descriptive analysis techniques were utilised to examine available crash and injury data. Analyses included cross tabulation and Pearson’s chi-squared tests (x^2) to examine relationships between factors and to identify associations between sub-groups of pedestrians and factors. Analyses were undertaken at a level of significance (α) of 0.05. Effect size was assessed using Cramer’s V statistic (ϕc). Trend data was analysed using log-linear regression models to assess estimated annual percentage change and 95th percentile confidence intervals (CI).

To complement the descriptive analysis, a mixed ecological study design was utilised to conduct retrospective analysis of pedestrian injuries in Victoria, Australia. The study design was utilised to assess differences in crash rates amongst various sub-groups of pedestrians and conduct time trend analysis to compare the changes in incident rates between 2009 and 2014/16. These years were selected as they correspond with two most recent iterations of the VISTA. The analysis focused on aggregate measures within each sub-group, allowing for linkage and comparison between the datasets utilised for incidence and exposure measures.

Injury incidence rates (IR) were calculated taking the frequency of cases of pedestrian from the VPARS data as the numerator and exposure measures of population, distance travelled, and number of trips from the household travel survey as the denominator. Incidence rates were compared for the most recent injury and household travel survey data across demographic variables (age, gender and metropolitan region), to identify subgroups with increased levels of risk.

Comparisons were also made between the two time periods to identify any changes in relative pedestrian injury risk over the five year time period between surveys. Where relative risk represents the incidents rates of an injury occurring in one group versus the incident rate of injury occurring in another group. Analyses were undertaken at a level of significance (α) of 0.05. Results are presented as incident rate ratios with 95th percentile confidence intervals (CI). Statistical analysis was undertaken using STATA 13 (StataCorp 2013) and IBM SPSS Statistics Version 25.

3.3 Results

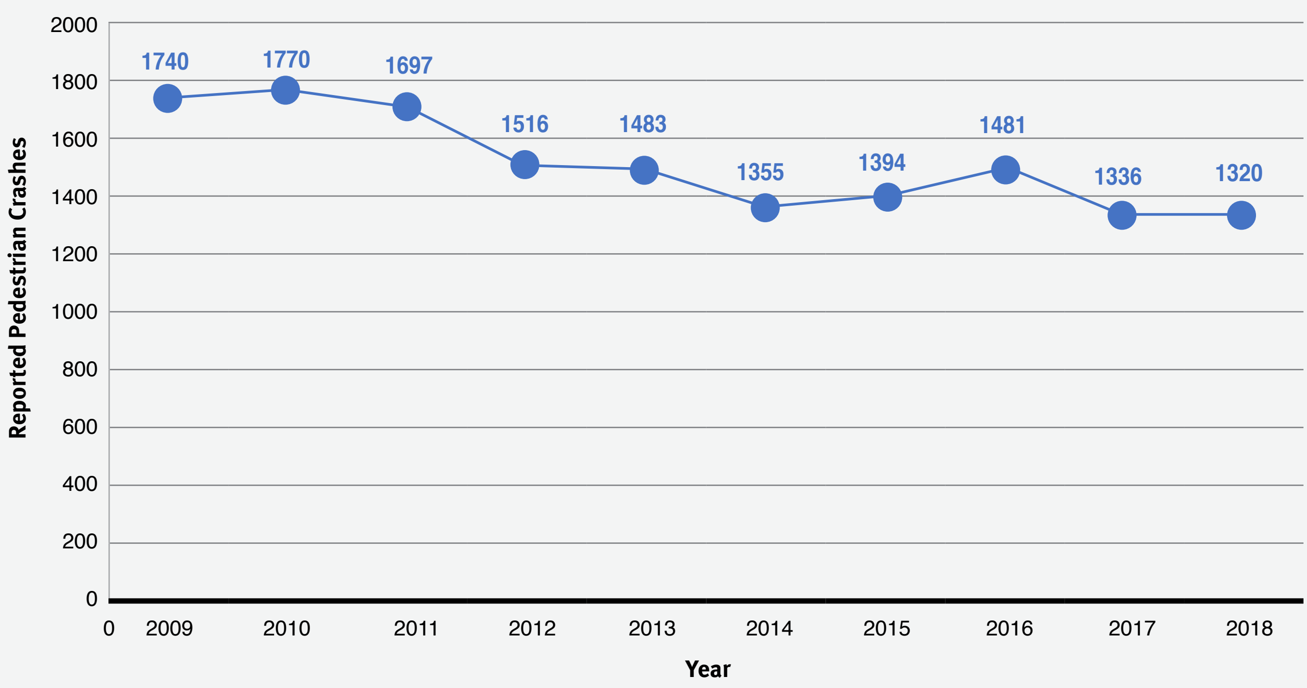
Results from the crash and injury datasets are presented separately in sections 4.1 to 6.1, travel behaviour and exposure measures are summarised in section 7.1, with the analysis of incident rates presented in section 7.2.

4 Police Data analysis

4.1 Overall Results

Between 2009 and 2018 a total of 15,092 injuries to a pedestrian, resulting from a crash, were reported to police and recorded in the Victoria Police Accident Records System (VPARS) dataset. Over the study period the number of crashes involving a pedestrian that were reported to police was found to have significantly decreased by 3.3 percent per annum (CI -3.9% to -2.8%) from 1,740 reported crashes in 2009 to 1,320 reported crashes in 2018 (Figure 1). However, it is noted that the reduction in reported crashes has remained reasonably constant over the past 5 years.

Figure 1: Reported pedestrian crashes (VPARS 2009-2018)



A summary of injured pedestrian demographics is presented in Table 1. Males were over-represented in the crash statistics, representing 51.3 percent of reported cases. Young adults were the most prevalent age group, representing 40.7 percent of injured pedestrians. Furthermore young males (0-39 years of age) were found to be involved in significantly more cases (29.0%) compared to females in the same age range (23.8%) ($x^2_{(5)} = 89.4$, $p < 0.01$, $\phi c = 0.077$). The data also indicates that adults aged 70 years and older are over-represented in police reported cases, representing 15 percent of all injury cases, while only representing 10.7 percent of the Victorian population (ABS 2016).

Police Data Analysis

The majority of crashes were reported within the Metropolitan Melbourne area (81.5%), albeit rural and regional Victoria were over-represented when considering population statistics. Children experienced higher rates of crash involvement in regional and rural areas compared to metropolitan Melbourne (14.8% vs 12.1%) as did older adults (70+) (18.3% vs 14.3%). Young adults (16-39) were more likely to be involved in a collision in a metropolitan area (42.4%) compared to regional or rural locations (34.9%) ($x^2_{(5)}$ = 74.1, $p < 0.01$, $\phi c = 0.071$). There were also gender differences when considering crash locations, with female pedestrians more likely to be involved in crashes in urban locations (48.4%), while the majority of crashes in rural areas involved males (55.1%) ($x^2_{(1)}$ = 20.2, $p < 0.01$, $\phi c = 0.035$).

Table 1: Demographic characteristics

Variables		Frequency (n)	Percent (%)
Gender	Male	7,736	51.3
	Female	7,177	47.6
	Unknown	179	1.2
Age Group	0-15yrs	1,873	12.4
	16-39yrs	6,137	40.7
	40-59yrs	3,172	21.0
	60-69yrs	1,468	9.7
	70+yrs	2,260	15.0
	Unknown	182	1.2
Geographic region (based on location of residence)	Melbourne Metropolitan Area	12,300	81.5
	Regional/Rural Victoria	2,561	17.0
	Unknown	231	1.5

Considering the crash details for police reported pedestrian injuries (Table 2), the majority of cases resulted in minor injuries (57.5%) to the pedestrian. However, there was a substantial proportion of collisions that were recorded as serious (39.9%) and required more substantial medical attention. The number of fatal injuries was relatively low. However, compared to the Cause of Death data reported in Section 3.3.3 there are fewer fatal cases in the police reported data. This could be due to the fact that Police-reported fatality data does not include pedestrian fatalities that occur ‘off-road’ (e.g., in car parks, driveways, private property), nor does it include intentional deaths. When comparing injury severity with age group, the highest rates of serious and fatal injuries involved pedestrians aged 60 years and older ($x^2_{(10)}$ = 515, $p < 0.01$, $\phi c = 0.176$) reflecting the increased vulnerability of older pedestrians.

Definition for Coding Accidents (DCA) codes were extracted for each reported case. The majority of pedestrian injuries occurred when the pedestrian was crossing the carriageway (56.0%). Other common collision types involved pedestrians emerging from between parked vehicles (5.5%) and injuries sustained in or on driveways (5.2%). A particularly concerning finding was that 15 percent of collisions were coded as Hit/Run, indicating that in these cases, the other road user (most often the driver of a vehicle) did not stay on site after the collision had occurred.

Table 2: Crash details

	Crash Details	Frequency (n)	Percent (%)
Injury level	Fatal	393	2.6
	Serious	6,021	39.9
	Other	8,678	57.5
Definition for Coding Accidents (DCA)	Nearside (100)	5,148	34.1
	Emerging (101)	827	5.5
	Far side (102)	3,306	21.9
	Playing, working, lying, standing on carriageway (103)	708	4.7
	Walking with traffic (104)	343	2.3
	Facing traffic (105)	163	1.1
	On median/ footpath (106)	420	2.8
	Driveway (107)	784	5.2
	Struck while boarding or alighting a vehicle (108)	409	2.7
	Other pedestrian (109)	1,834	12.2
	Other	1,150	7.6
Hit/Run	Yes	2,268	15.0
	No	12,642	83.8
	Unknown	182	1.2

4.2 Vehicle and Driver Characteristics

Analysis of the counterpart involved in the pedestrian injury identified that most frequently collisions involved cars including station wagons, utility vehicles and panel vans, representing almost three quarters of collision counterparts (73.4%) (Table 3). Apart from taxis, the remaining vehicle types each represented less than 2 percent of collision counterparts. However, it was notable that the counterpart was unknown in 15.5 percent of cases.

Not surprisingly the majority of pedestrian crashes resulted in no damage (44.5%) or only minor damage (23.9%) to the vehicle involved in the collision. Analysis of vehicle movement, as reported by the police, indicated that the majority of collision involved a vehicle travelling straight ahead (43.5%), followed by left (8.5%) and right turning vehicle movements (15.7%).

Table 3: Counterpart characteristics

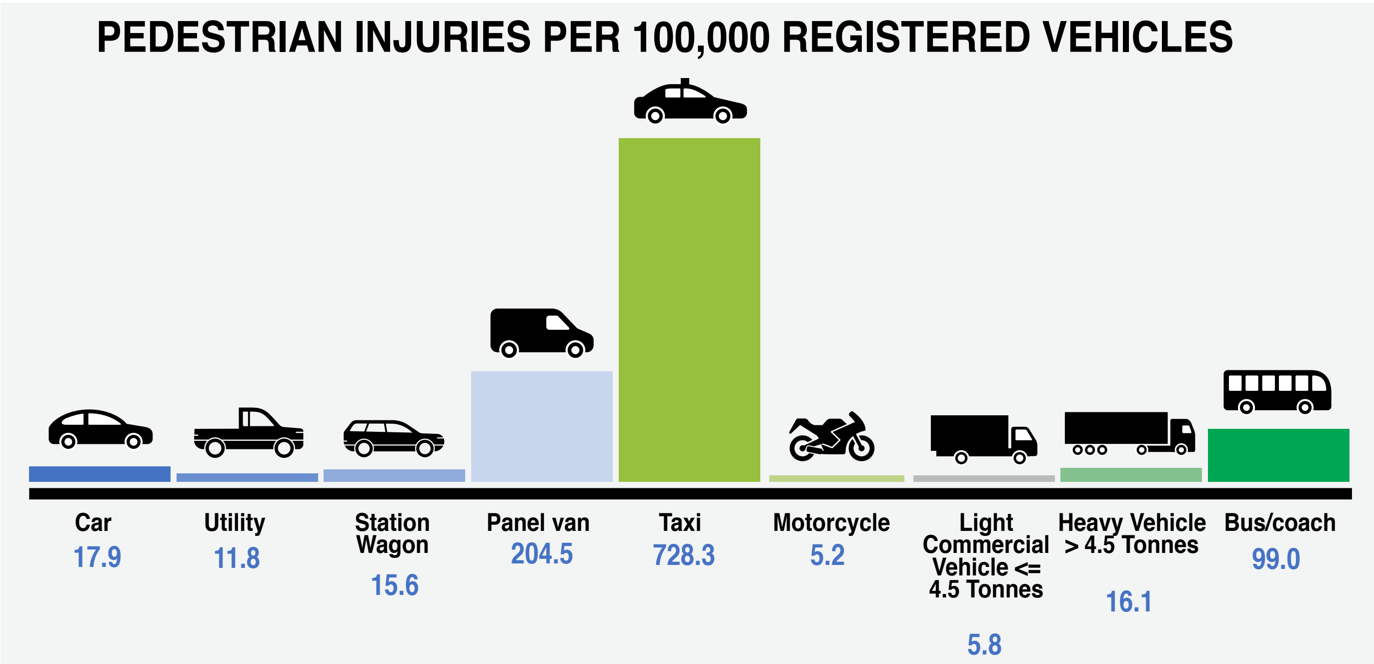
Counterpart Characteristics		Frequency (n)	Percent (%)
Vehicle type	Car	7,365	48.8
	Utility	945	6.3
	Station wagon	2,353	15.6
	Panel van	378	2.5
	Taxi	511	3.4
	Motorcycle	170	1.1
	Motor scooter/moped	22	0.1
	Bicycle	150	1.0
	Light Commercial Vehicle (Rigid) <= 4.5 Tonnes	138	0.9
	Heavy Vehicle (Rigid) > 4.5 Tonnes	204	1.4
	Train	7	0.0
	Tram	208	1.4
	Bus/coach	222	1.5
	Other	74	0.5
	Unknown	2,345	15.5
Level of damage	Minor	3,604	23.9
	Moderate - Driveable Vehicle	777	5.1
	Moderate - Unit Towed Away	466	3.1
	Major - Unit Towed Away	114	0.8
	Extensive - Unrepairable	57	0.4
	Nil Damage	6,713	44.5
	Not Known	1,995	13.2
	Not reported	1,366	9.1
Vehicle movement	Going Straight Ahead	6,563	43.5
	Turn Right	2,364	15.7
	Turn Left	1,276	8.5
	Leaving a Driveway	316	2.1
	Reversing	1,012	6.7
	Parking - into / Out	338	2.2
	Other	671	4.4
	Not Known	1,184	7.8
	Not reported	1,368	9.1

Police Data Analysis

To assess the risk posed to pedestrians by different vehicle types, comparisons were made between the vehicle classifications provided in the VPARS dataset (Table 3) and the number of registered vehicles by each vehicle classification type in Victoria. Table 4 provides a summary of the registered vehicles. Using the collision counterparts as a measure of incidence and registered vehicles as a measure of exposure, it can be seen that per 100,000 registered vehicles taxis were disproportionately involved in pedestrian crashes. Similarly, there were high rates of crashes involving mopeds and scooters and buses compared to the proportion of registered vehicles. The relative risk of crashes with bicycles cannot be assessed using this method, as they are not registered vehicles.

Table 4: Pedestrian collision counterpart vs registerations 2009 -2018

Vehicle type	Register Vehicles	Counterparts/ 100,000 registered vehicles
Car	41,042,383	17.9
Utility	8,002,233	11.8
Station wagon	15,101,506	15.6
Panel van	184,851	204.5
Taxi	70,160	728.3
Motorcycle	3,253,166	5.2
Motor scooter/moped	14,220	154.7
Light Commercial Vehicle (Rigid) <= 4.5 Tonnes	2,397,021	5.8
Heavy Vehicle (Rigid) > 4.5 Tonnes	1,269,740	16.1
Bus/coach	224,331	99.0



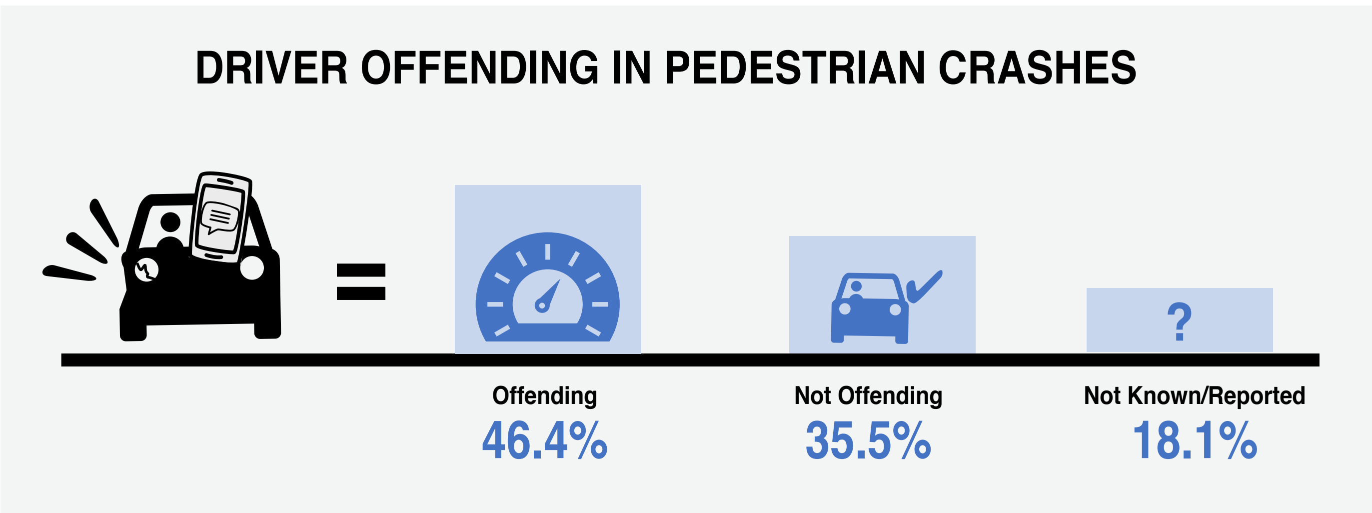
Police Data Analysis

Analysis of demographic characteristics of the vehicle operator indicated a relatively even split between male (51.3%) and female (47.6%) drivers (Table 5). Police reported the driver involved in the collision as offending in 46.4 percent of collisions, while 35.5 percent were not considered as offending and for 18.1 percent this was not known or reported.

Considering the possible contributing factors reported by police, preliminary breath testing indicated that 1.1 percent of vehicle operators recorded a positive Blood Alcohol Concentration (BAC) reading. Mobile phone use by the vehicle operator was identified in 50 cases over the study period, however it was unknown in 40.8 percent of cases.

Table 5: Vehicle operator characteristics

Demographics		Frequency (n)	Percent (%)
Gender	Female	7,177	47.6
	Male	7,736	51.3
	Unknown	179	1.2
Offending	Yes	7,007	46.4
	No	5,351	35.5
	Not known	1,369	9.1
	Not reported	1,362	9 .0
Preliminary Breath Test	Negative	9366	62.1
	Positive	160	1.1
	Not reported	5566	36.9
Mobile Phone	Yes	50	0.3
	No	7,264	48.1
	Not known	6,162	40.8
	Not reported	1,616	10.7

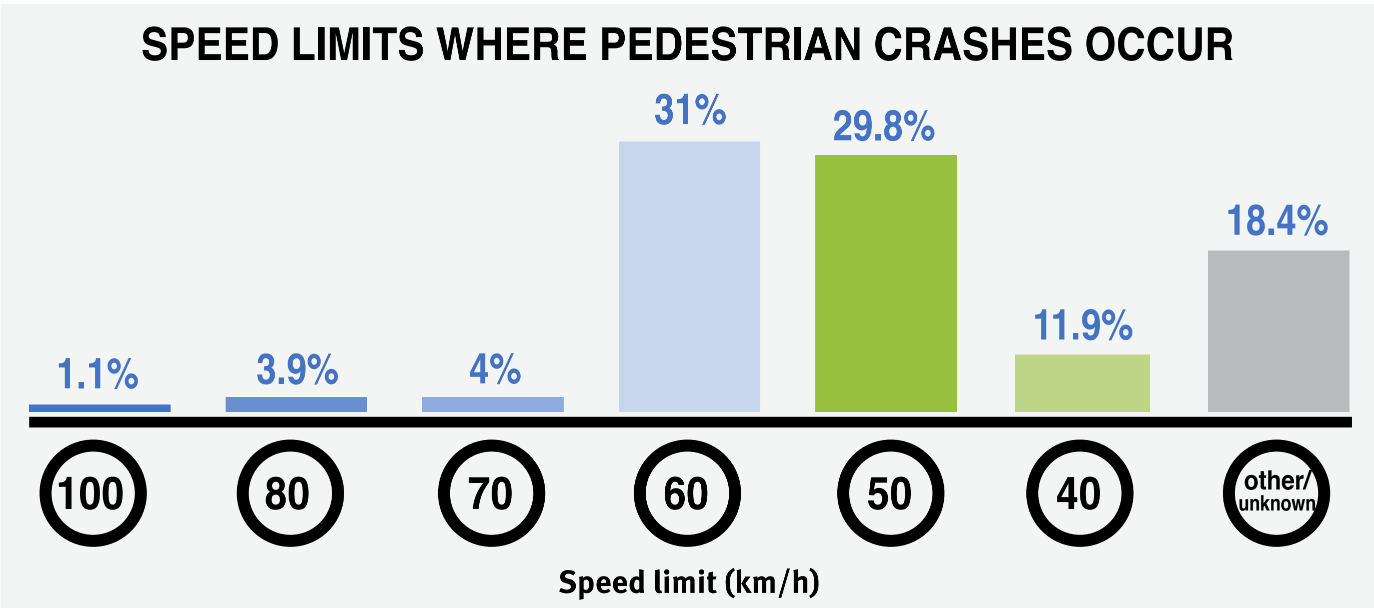


4.3 Road Environment and Spatial Analysis

Road environment conditions were analysed. Regarding collision location, there was a roughly even split between collisions at and away from intersections (Table 6). The majority of pedestrian crashes were found to occur on roads with posted speed limits of 60 km/h or less (75.3%). Furthermore, there was a significant relationship between speed environment and injury severity with fatal and serious injuries significantly more likely on roads with speed limits of 80 km/h or above ($x^2_{(2)} = 331$, $p < 0.01$, $\phi c = 0.160$), confirming the increased risk of serious injury for pedestrians in higher speed environments. It is noted that the data did not provide an indication of vehicle travel speed on impact.

Table 6 Road environment details

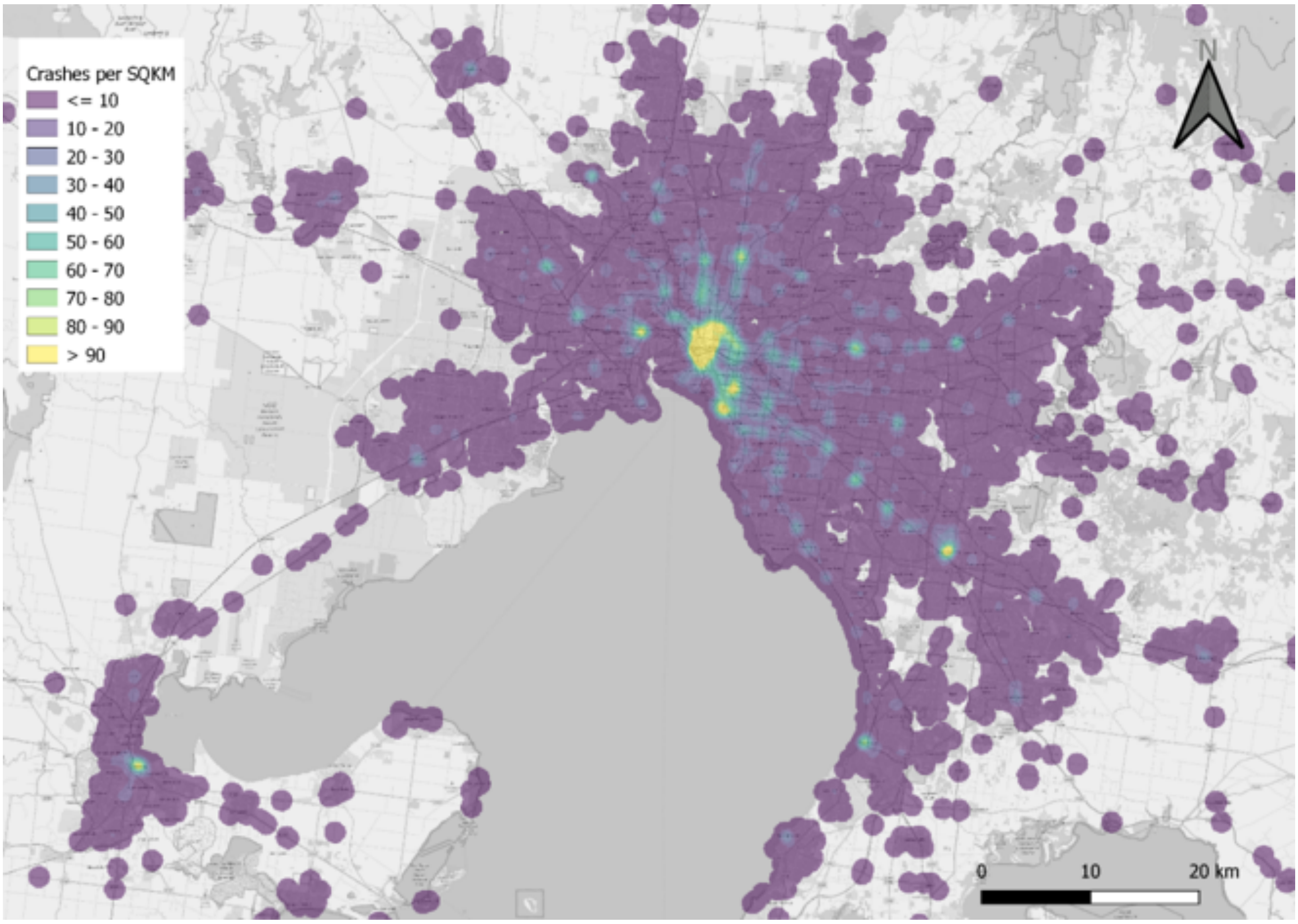
Variables		Frequency (n)	Percent (%)
Speed limit (km/h)	110	13	0.1
	100	159	1.1
	90	11	0.1
	80	585	3.9
	70	611	4.0
	60	4,677	31.0
	50	4,500	29.8
	40	1,798	11.9
	30	104	0.7
	Other	2634	17.5
Road infrastructure	Intersection	7,373	48.9
	Non-intersection	7,656	50.7
	Unknown	62	0.4



Police Data Analysis

Spatial analysis of collisions involving injured pedestrians over the study period indicate a number of locations with high collision rates Figure 2. The highest concentration of crashes occurred in the Melbourne CBD with the cluster extending from Southbank to Carlton. Other sizeable clusters in the inner city area included St Kilda, Prahran and Footscray. Outside of the inner city, clusters of crashes were also identified in Preston, Dandenong, Frankston, Geelong and Werribee. In addition, analyses revealed that there were also less prominent clusters at many major intersections, particularly along major arterial corridors, and in the vicinity of railway stations. This is likely a reflection of the increased pedestrian activity at these locations.

Figure 2: Pedestrian crash density (2009 – 2018)



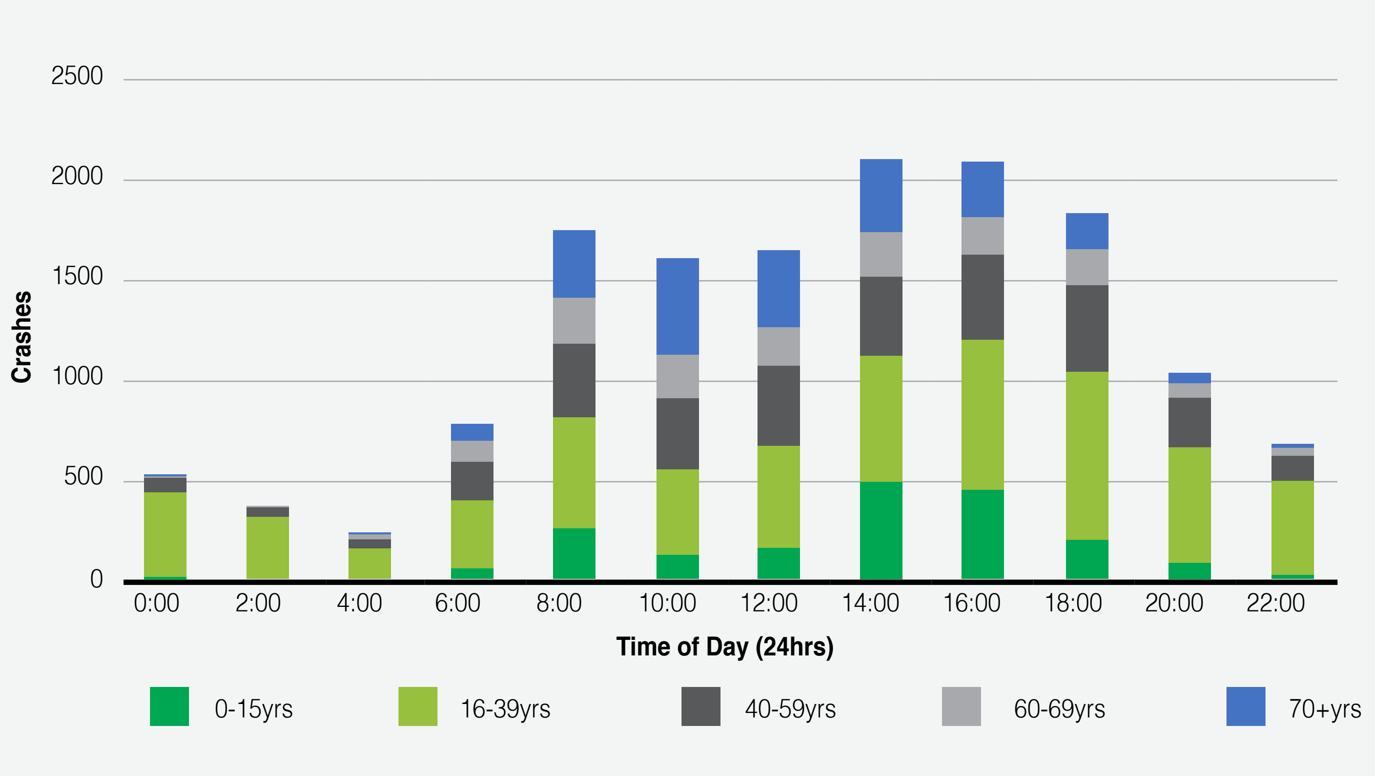
When considering the spatial distribution of collisions by Local Government Area (Table 7), the highest proportion of injuries were identified in the City of Melbourne (10.9%), followed by Moreland City Council and the City of Boroondara. Interestingly, the number of collisions were lower in the City of Port Phillip and the City of Stonnington, which was somewhat unexpected given the clusters in St Kilda and Prahran. Outside of Metropolitan Melbourne, the LGAs with the highest proportion of collisions included Geelong, Ballarat, Bendigo, Latrobe and Shepparton.

Table 7: Local Government Areas with highest proportion of pedestrian crashes

Local Government Area		Frequency (n)	Percent (%)
Metropolitan Melbourne	Melbourne	1,639	10.9
	Moreland	626	4.1
	Boroondara	568	3.8
	Dandenong	556	3.7
	Yarra	555	3.7
	Darebin	528	3.5
	Stonnington	522	3.5
	Glen Eira	512	3.4
	Monash	501	3.3
	Port Phillip	482	3.2
Regional Victoria	Geelong	561	3.7
	Ballarat	238	1.6
	Bendigo	208	1.4
	Latrobe	154	1.0
	Shepparton	126	0.8

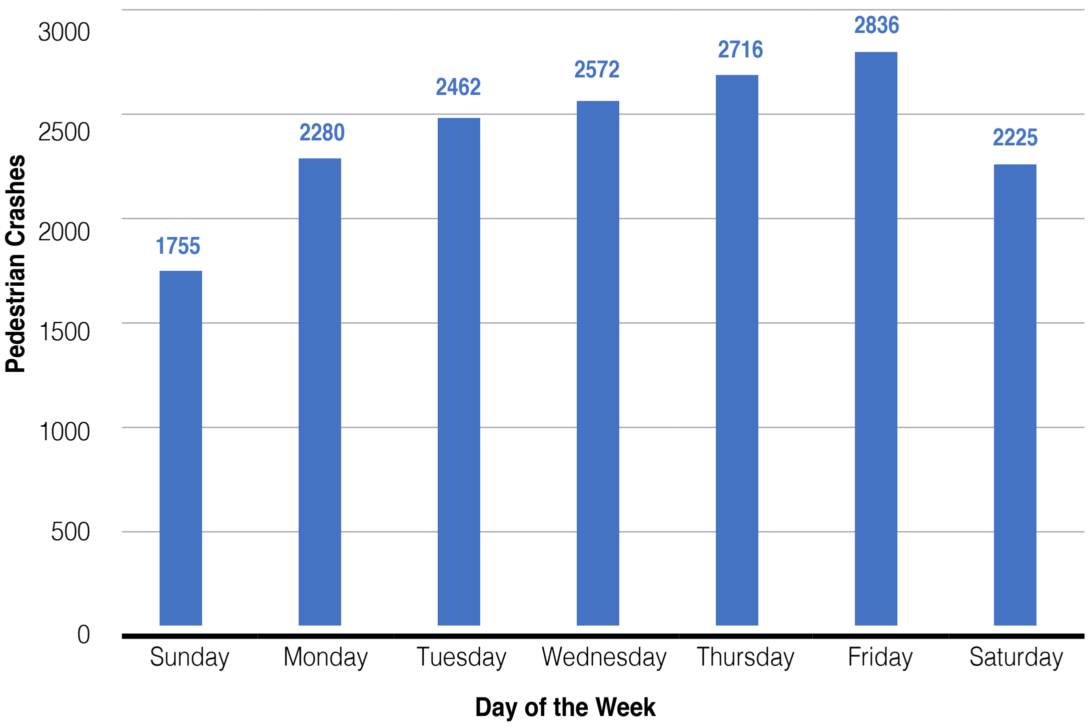
4.4 Timing of Crashes

Figure 3: Pedestrian reported crashes by Time of Day (2009-2018)



Within the VPARS dataset, temporal variables were examined for time of day, day or week and month of year of pedestrian injury collisions. The temporal distribution of injury collisions through the day are presented in Figure 3. When considering crashes involving pedestrians between 2009 and 2018, the highest proportion occurred in the afternoon, between 2:00pm and 3:59pm (14.4%), closely followed by the 4:00pm to 5:59pm time period (14.3%). There was also a noticeable peak between 8:00am and 9:59am, with 12.0 percent of collisions reported between these times. When considering gender differences, males were over-represented in collisions that occurred at night, most notably between 10:00pm and 5:59am ($x^2_{(11)} = 389$, $p < 0.01$, $\phi c = 0.164$). Furthermore, during this time period, the majority of injury collisions involved pedestrians aged between 16 and 39 years of age, which is likely a reflection of the increased exposure for this age group during these time periods. As expected, crashes involving older adults were more common during daylight hours, reflecting their prevalence during these time periods.

Figure 4: Pedestrian reported crashes by Day of Week (2009-2018)



When considering the day of the week, the highest proportion of injury collisions occurred on Friday (17.1%). Again, there was a significant correlation between gender and day of the week, with males representing significantly more cases on Saturday and Sunday compared to females ($x^2_{(6)}$ = 56.5, $p < 0.01$, ϕc = 0.062). Injury collisions on Saturday and Sunday were also more likely to involve adults aged between 16 and 39 years.

Police Data Analysis

When considering the month of the year, June had the highest number of reported pedestrian collisions, followed by May and July. Interestingly, when considering lighting conditions, June had the fewest crashes that occurred in daylight hours and the highest proportion occurring when it was dark. While this is somewhat expected given the winter solstice is in June, it may also indicate an increased risk for pedestrians when it is dark or in wet weather. Notwithstanding, the majority of pedestrian collisions occurred in clear weather conditions and during daylight hours (Table 8).

Figure 5: Pedestrian crashes by Month of Year (2009 – 2018)

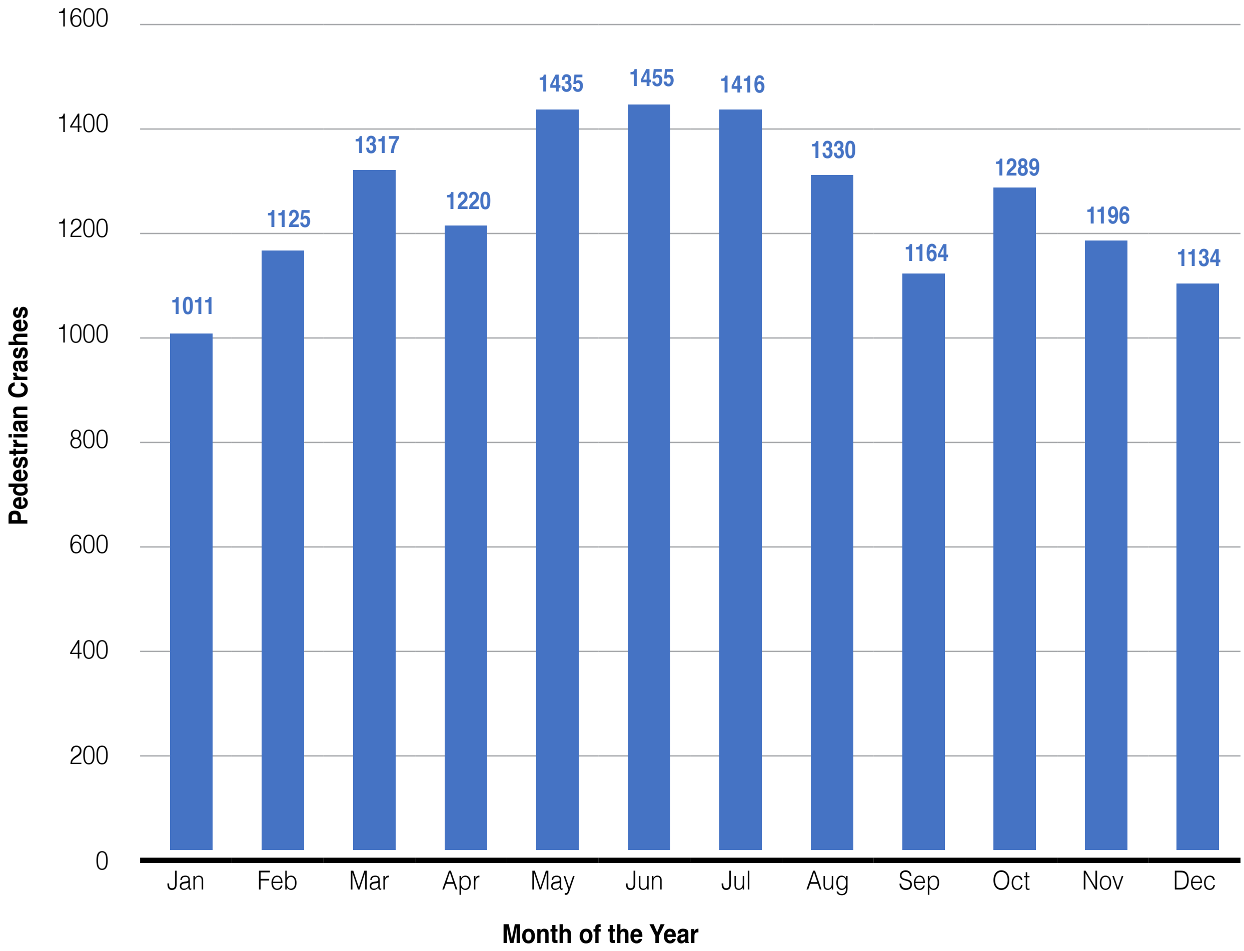
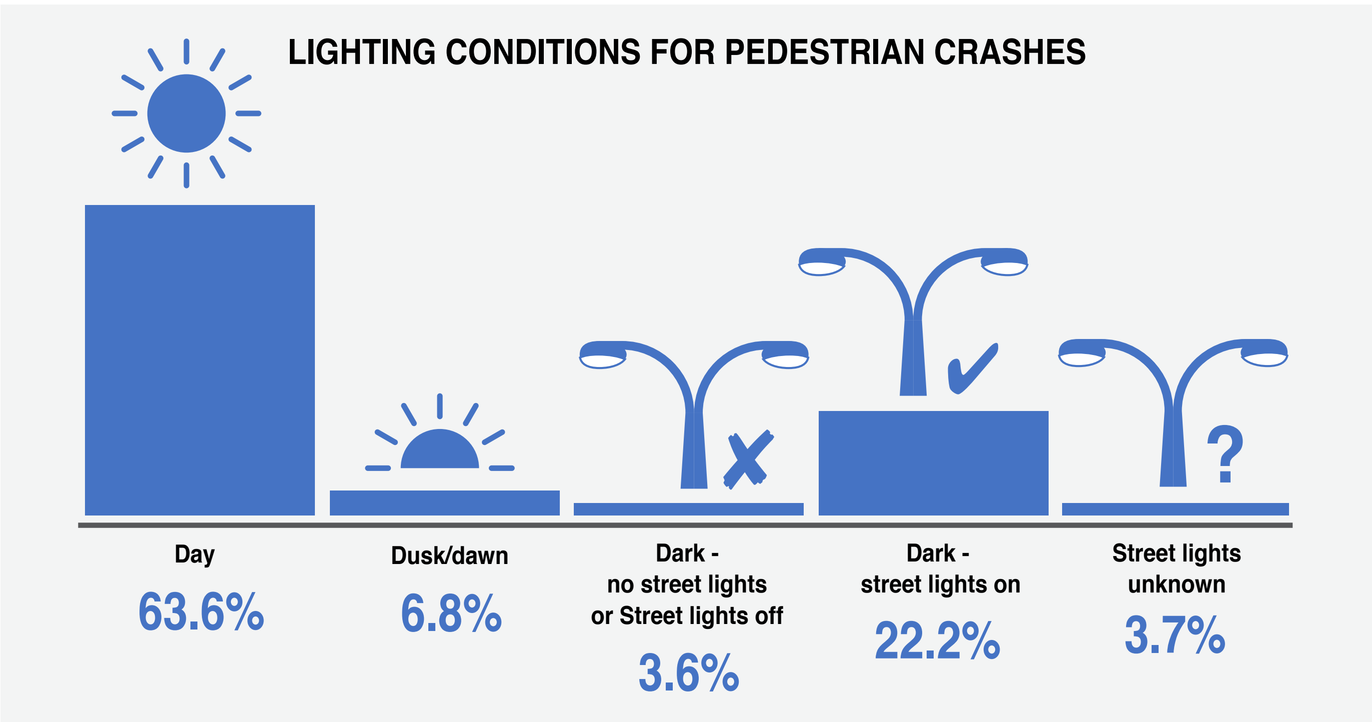


Table 8: Crash environmental conditions

Environmental condition		Frequency (n)	Percent (%)
Atmospheric	Clear	12,436	82.4
	Rain	1,398	9.3
	Fog	59	0.4
	Dust	11	0.1
	Strong wind	10	0.1
	Smoke	9	0.1
	Snow	3	0.0
	Unknown	1,166	7.7
Lighting	Day	9,601	63.6
	Dusk/dawn	1,032	6.8
	Dark - no street lights	490	3.2
	Dark - street lights on	3,353	22.2
	Dark - street lights off	53	0.4
	Dark - street lights unknown	276	1.8
	Unknown	287	1.9

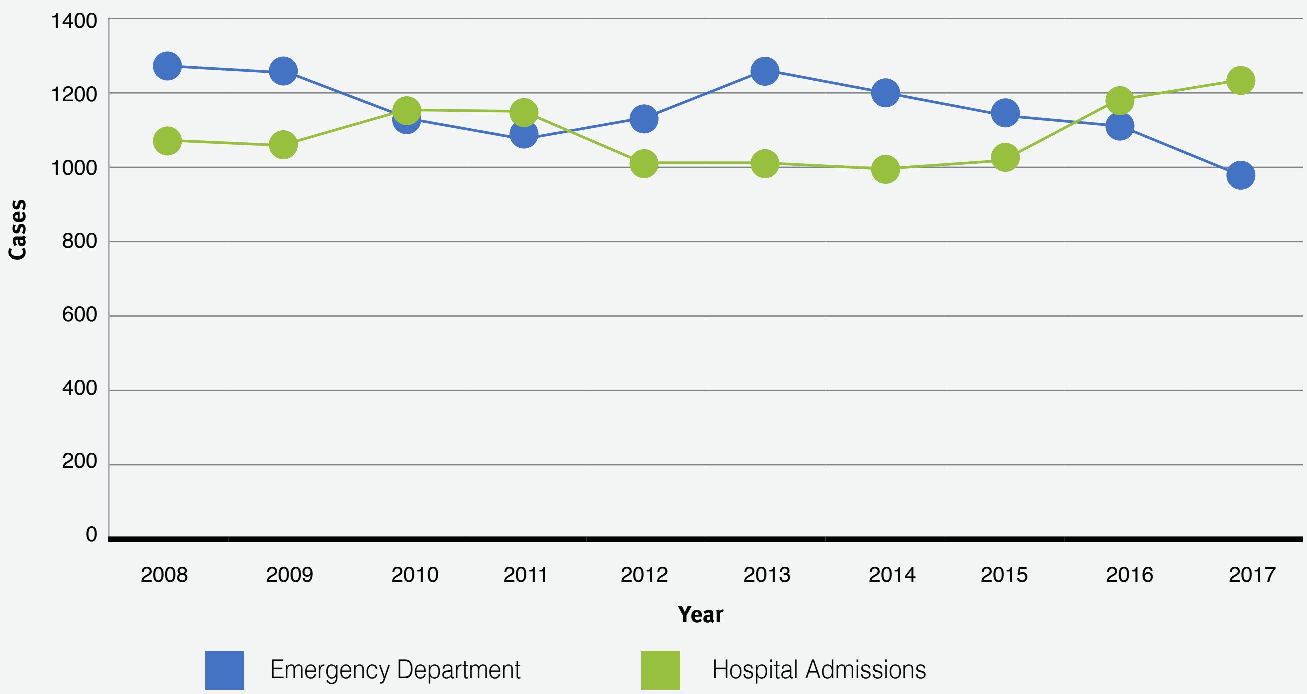


5 Hospital Data Analysis

5.1 Analysis of Injuries

Analysis of pedestrian injury data recorded in the Victoria Injury Surveillance dataset revealed that between 2008 and 2017 there were at least 10,845 hospital admissions and 11,590 emergency department presentations involving an injured pedestrian. Over the study period the number of emergency department presentations decreased by a statistically significant 1.54% per annum (CI = -2.20% to -0.91%). On average there was an increase in hospital admissions by 0.65 percent (-0.01 to 1.31%), however the change was not statistically significant (p = 0.053) (Figure 6).

Figure 6: VISU cases (2008-2017)



Analysis of demographics identified that males represented the majority of admissions (54.9%) and emergency department presentations (51.9%). Pedestrians in the 15-34 year age group represented the majority of admissions and presentations, followed by the 35 to 64 year age group (Table 9). However when adjusting for population, pedestrians aged 75 years and older had the highest rates of admissions and presentations. Across both datasets the majority of cases were recorded in the Melbourne Metropolitan Area (78.6% for hospital admissions and 75.7% for emergency department presentations).

Hospital Data Analysis

Table 9: VISU Demographic summary

Demographics		Admissions		Emergency Department Presentations	
		Frequency (n)	Percent (%)	Frequency (n)	Percent (%)
Gender	Male	5,952	54.9	6,010	51.9
	Female	4,893	45.1	5,580	48.1
Age Group	0-14yrs	1,135	10.5	1,526	13.2
	15-34yrs	3,485	32.1	4,367	37.7
	35-64yrs	3,328	30.7	3,542	30.6
	65-74yrs	1,108	10.2	920	7.9
	75-84yrs	1,180	10.9	844	7.3
	85+yrs	609	5.6	391	3.4

When considering the types of injuries sustained, the most commonly injured body region was the head, followed by injuries to the knee and lower leg and ankle and foot (Table 10). Across the two datasets, fractures were the most common type of injury representing 21.3 percent of cases to the ED and 44.5 percent of hospital admissions (Table 11). Superficial injuries (15.4%) and dislocations, sprains and strains (19.9%) were the next most common injuries resulting in emergency department presentations, while intracranial injuries (11.7%), followed by superficial injuries (11.5%) and open wounds (10.3%) were the most common injuries requiring hospital admission, reflecting the increased severity of the injuries requiring hospitalisation.

Table 10: Grouped body site injured

Grouped body site injured	Admissions		Emergency Department Presentations	
	Frequency (n)	Percent (%)	Frequency (n)	Percent (%)
Head	2,938	27.1	1762	15.2
Knee & lower leg	2,385	22.0	1753	15.1
Abdomen, lower back, lumbar spine & pelvis	1,080	10.0	572	4.9
Ankle & foot	825	7.6	2191	18.9
Hip & thigh	779	7.2	623	5.4
Shoulder & upper arm	741	6.8	475	4.1
Thorax	658	6.1	293	2.5
Elbow & forearm	608	5.6	481	4.2
Wrist & hand	319	2.9	476	4.1
Neck	278	2.6	190	1.6
Multiple body regions	13	0.1	2336	20.2
Unspecified body region	66	0.6	352	3.0
Other	65	0.6	86	0.7
Missing injury code	90	0.8	-	-
Total	**10,845**	**100**	**11,590**	**100**

Hospital Data Analysis

Table 11: Grouped nature of main injury

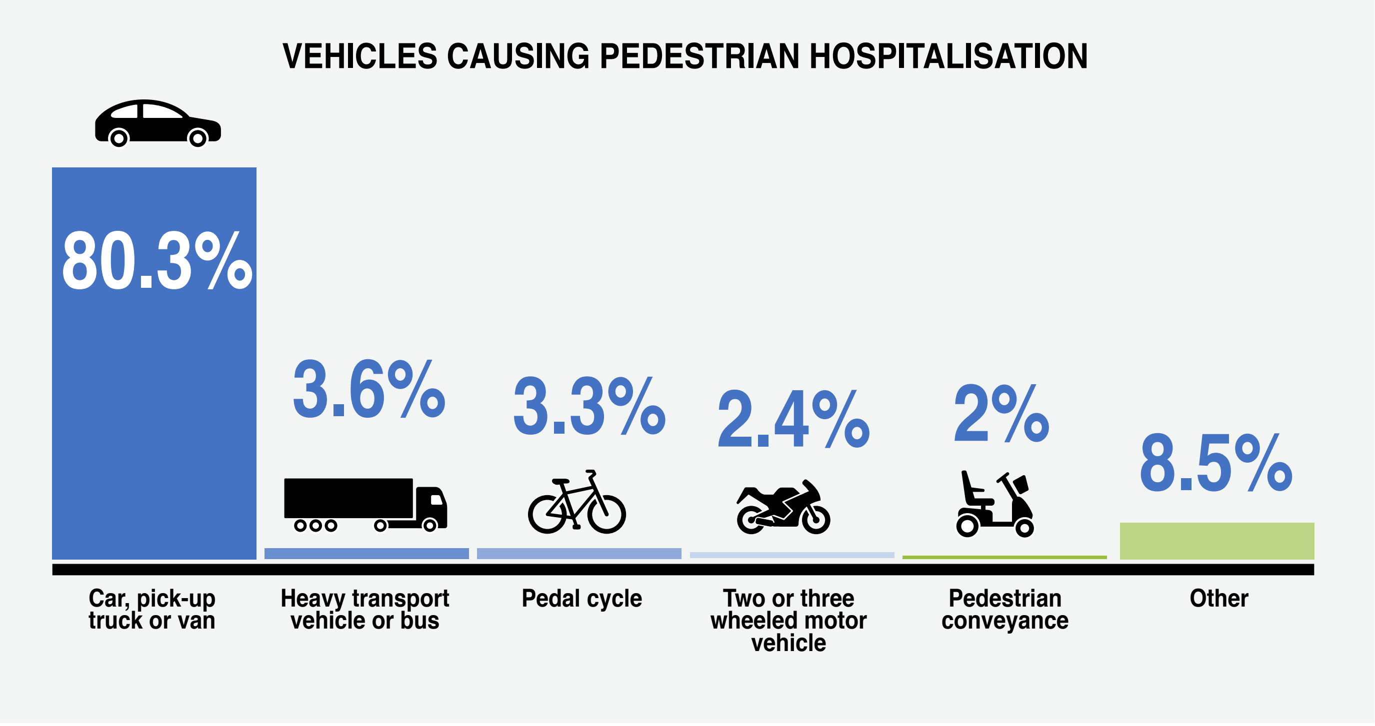
Grouped nature of main injury	Admissions		Emergency Department Presentations	
	Frequency (n)	Percent (%)	Frequency (n)	Percent (%)
Fracture	4,823	44.5	2466	21.3
Intracranial injury	1,273	11.7	428	3.7
Superficial injury	1,245	11.5	1786	15.4
Open wound	1,117	10.3	799	6.9
Dislocation, sprain & strain	391	3.6	2302	19.9
Injury to internal organs	257	2.4	159	1.4
Injury to muscle & tendon	140	1.3	693	6.0
Crushing injury	58	0.5	275	2.4
Injury to nerves & spinal cord	39	0.4	17	0.1
Traumatic amputation	25	0.0	6	0.1
Injury to blood vessels	25	0.2	29	0.3
Eye injury- excluding foreign body	15	0.0	13	0.1
Other & unspecified injury/ missing	1,409	0.2	2617	22.6

Cases requiring hospitalisation were classified using ICD 10AM. Analysis of the cause code identified that the majority of hospital admissions were due to a pedestrian being injured in a collision with a car (80.3%), this was followed by collisions with heavy vehicles (3.6%) and unspecified cases (5.7%) (Table 12).

5.2 Vehicle Characteristics

Table 12: Hospitalisations by ICD 10AM cause code

ICD 10 AM Cause Code	Frequency (n)	Percent (%)
Pedestrian injured in collision with car, pick-up truck or van	8,704	80.3
Pedestrian injured in other and unspecified transport accidents	619	5.7
Pedestrian injured in collision with heavy transport vehicle or bus	388	3.6
Pedestrian injured in collision with pedal cycle	356	3.3
Pedestrian injured in collision with two- or three-wheeled motor vehicle	258	2.4
Pedestrian injured in collision with pedestrian conveyance (i.e. skateboard, wheelchair, mobility scooter etc.)	216	2.0
Pedestrian injured in collision with other non-motor vehicle	162	1.5
Pedestrian injured in collision with railway train or railway vehicle	142	1.3
Total	**10,845**	**100**

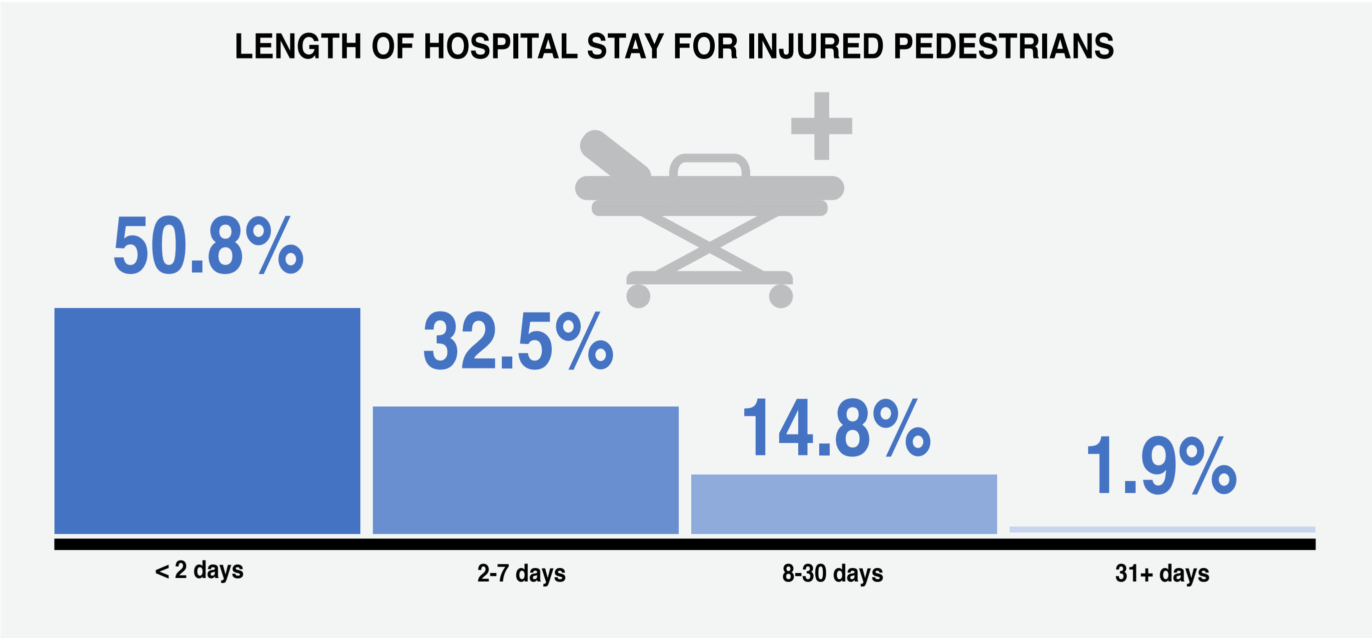


5.3 Length of Hospital Stay

Analysis of the length of hospital stay required by injured pedestrians identified that just over half of admissions were less than 2 days in duration (50.8%). However, there was a small proportion of cases that required extensive medical treatment, with 1.9 percent of cases requiring hospitalisation for over a month as a result of their injuries.

Table 13: Length of Hospital Stay

Length of Hospital Stay	Frequency (n)	Percent (%)
< 2 days	5511	50.8
2-7 days	3523	32.5
8-30 days	1603	14.8
31+ days	208	1.9
Total	**10,845**	**100.0**

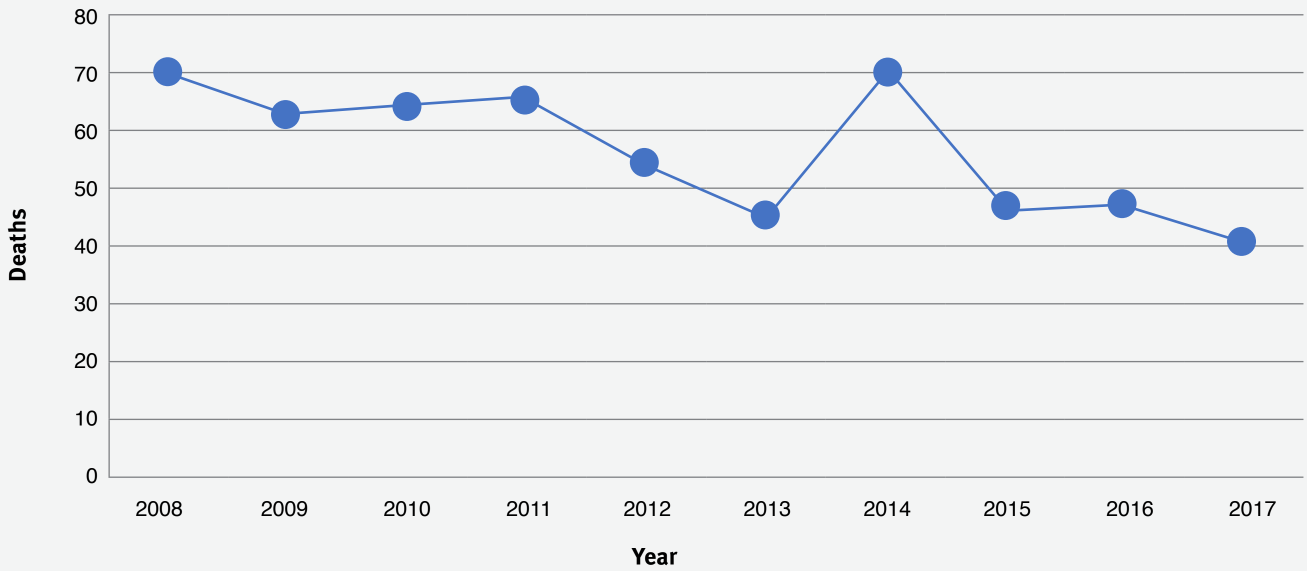


6 Fatality Data Analysis

6.1 National Cause of Death Unit Record File

Pedestrians deaths recorded in the National Cause of Death Unit Record File were extracted for the most recent 10 years of data. Limited information was available covering only age, gender and cause codes. Between 2008 and 2017 there was an average of 56.4 fatal pedestrian injuries recorded per annum in Victoria (Figure 7).

Figure 7: CODERF cases (2008-2017)



Males were over-represented amongst pedestrian fatalities, representing 66.0 percent of reported cases (Table 14). Further, middle aged adults (35-64yrs) represented the highest proportion of fatal injuries (30.1%), followed by adults in the 15 to 34 age range (20.7%). When controlling for population, there was a positive relationship between age and crash risk, with increasing fatal rates observed as pedestrians age increased.

Table 14: CODERF demographics (2008-2017)

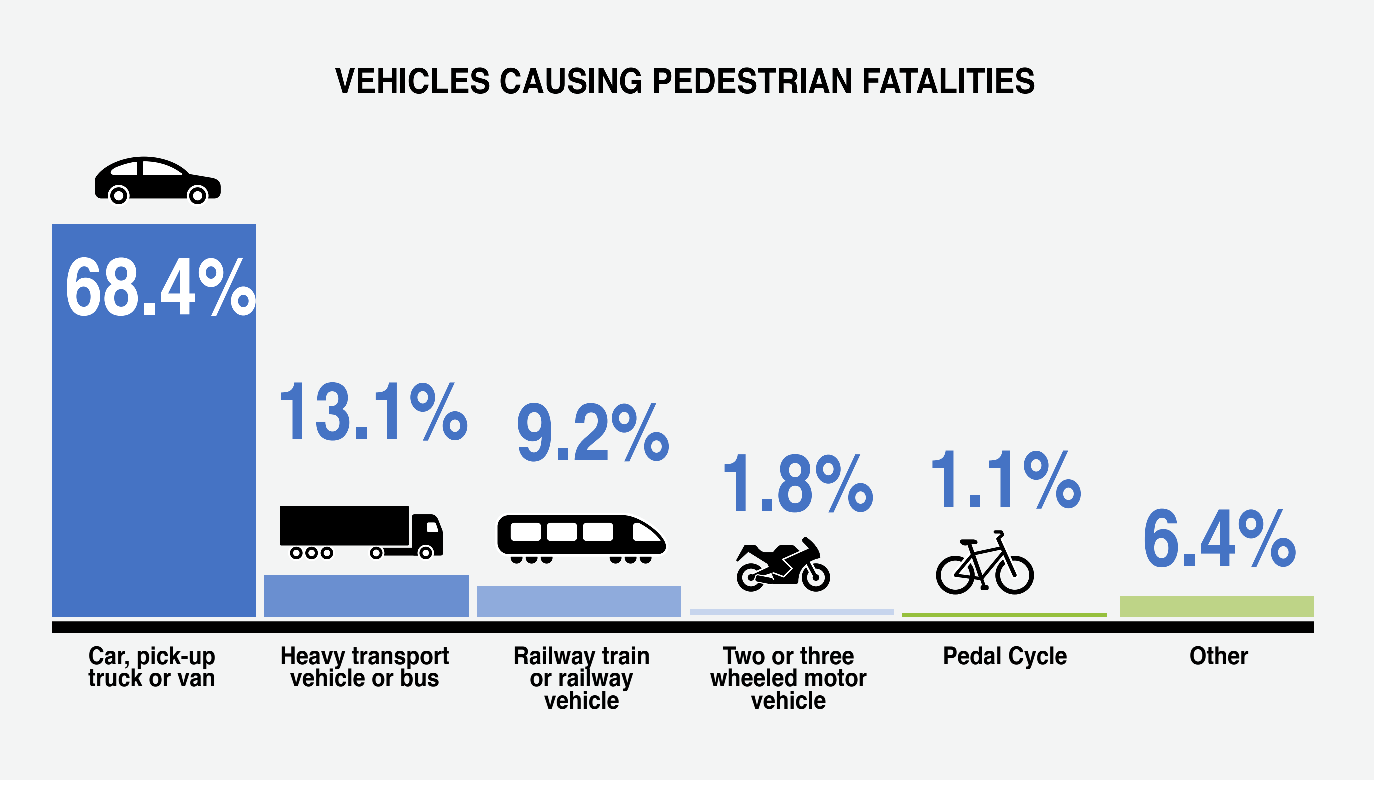
Demographics		Frequency (n)	Percent (%)
Gender	Male	372	66.0
	Female	192	34.0
Age Group	0-14yrs	43	7.6
	15-34yrs	117	20.7
	35-64yrs	170	30.1
	65-74yrs	66	11.7
	75-84yrs	95	16.8
	85+yrs	73	12.9
Total		**564**	**100.0**

Fatality Data Analysis

Summaries of ICD 10AM Cause Code attributed to each case identified that the majority of cases involved a pedestrian being injured due to a collision with a car (68.4%). This was followed by heavy transport vehicles or buses 13.1%). Heavy vehicles and buses were involved in fewer crashes overall, demonstrating the increased injury severity for pedestrians when a collision does occur (Table 15).

Table 15: CODERF ICD 10AM Cause Code (2008-2017)

ICD 10AM Cause Code	Frequency (n)	Percent (%)
Pedestrian injured in collision with car, pick-up truck or van	386	68.4
Pedestrian injured in collision with heavy transport vehicle or bus	74	13.1
Pedestrian injured in collision with railway train or railway vehicle	52	9.2
Pedestrian injured in other and unspecified transport accidents	30	5.3
Pedestrian injured in collision with two- or three-wheeled motor vehicle	10	1.8
Pedestrian injured in collision with other non-motor vehicle	6	1.1
Pedestrian injured in collision with pedal cycle	6	1.1
Total	**564**	**100.0**



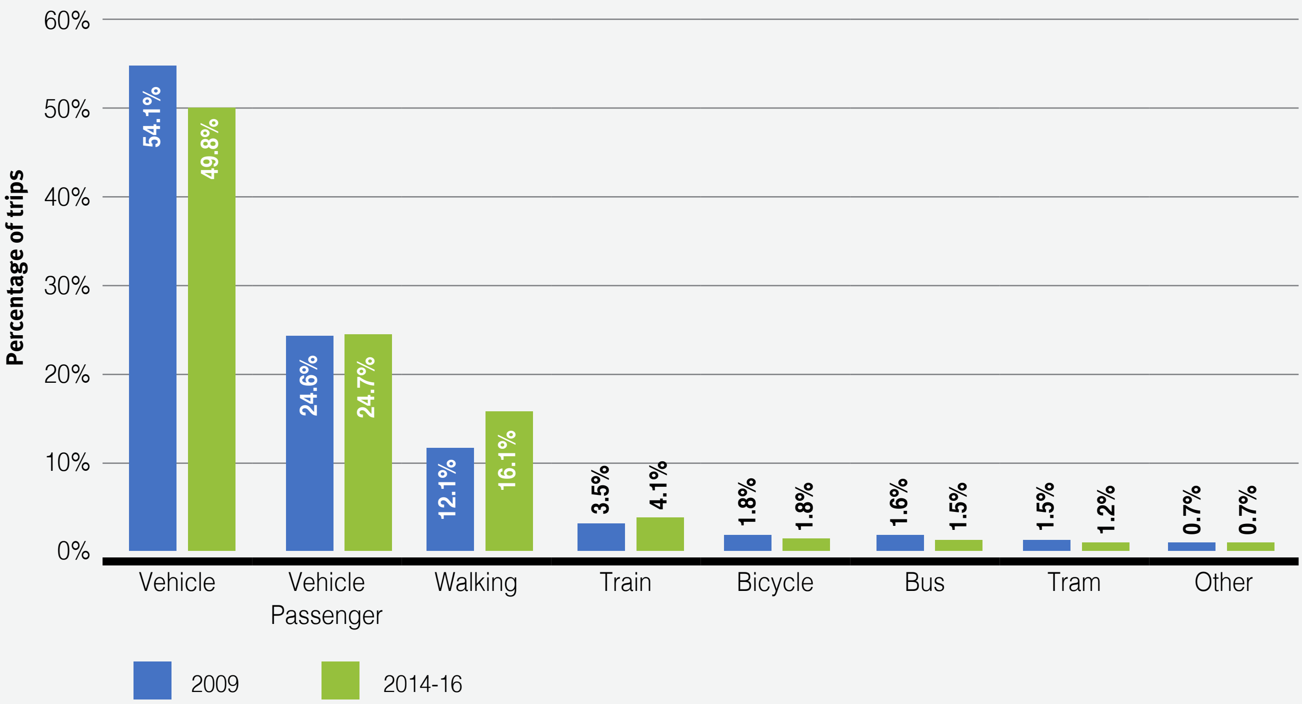
7 Pedestrian Exposure Analysis

7.1 Pedestrian Exposure

Exposure data was sourced from the VISTA household travel surveys. Analysis considered walking trips, duration and distance as measures of exposure. Based on data from the VISTA travel survey, it is estimated that the proportion of trips made by walking increased when comparing mode share from the 2009 and 2014/16 VISTA surveys (12.1% vs 16.3%) (Figure 8). It is noted that these are trips undertaken predominantly by walking. There are many more trips, particularly using public transport, that include a walking component, that were not captured in this analysis.

The most popular mode of transport was private motor vehicle, representing approximately 75 percent of trips in the 2014 to 2016 survey data.

Figure 8: VISTA Mode share by total trips



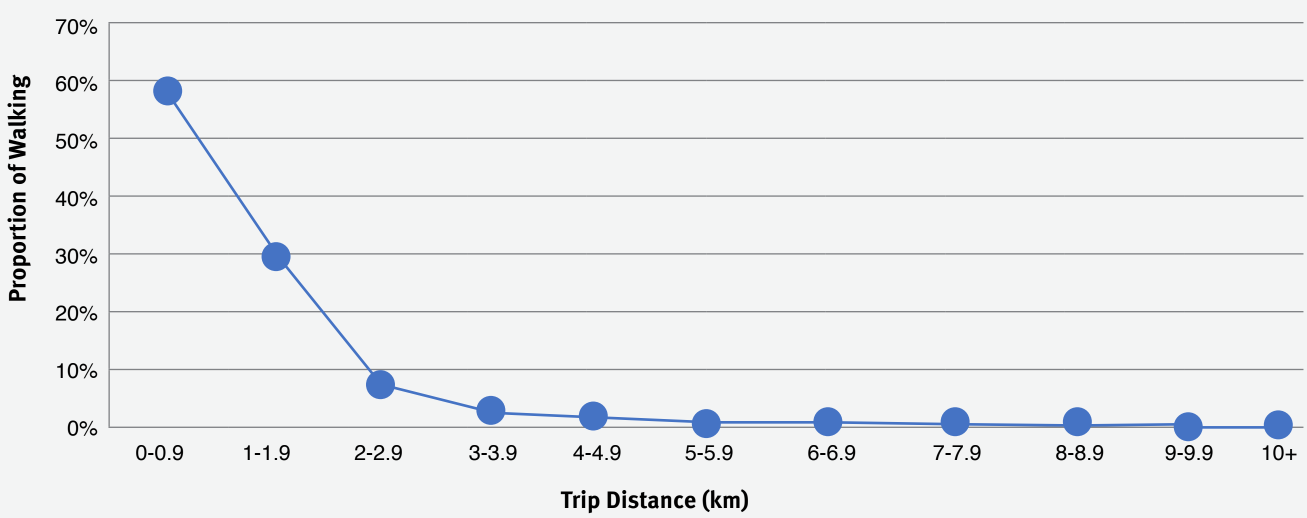
Pedestrian Exposure Analysis

Table 16: VISTA Walking Trips by Purpose

Trip Purpose	2014-2016	
	Frequency	Percent
Recreational	524,004	23.1
Personal Business	433,792	19.1
Social	356,116	15.7
Buy Something	340,580	15.0
Work Related	202,607	8.9
Education	174,202	7.7
Accompany Someone	113,519	5.0
Pick-up or Drop-off Someone	84,806	3.7
Pick-up or Deliver Something	32,702	1.4
Other Purpose	10,952	0.5

Analysis of walking trip purpose identified that walking trips were most commonly recreational (23%), followed by trips to undertake personal business and for social purposes (Table 16).

Figure 9: VISTA 2014-16 Walking trips by distance



Pedestrian Exposure Analysis

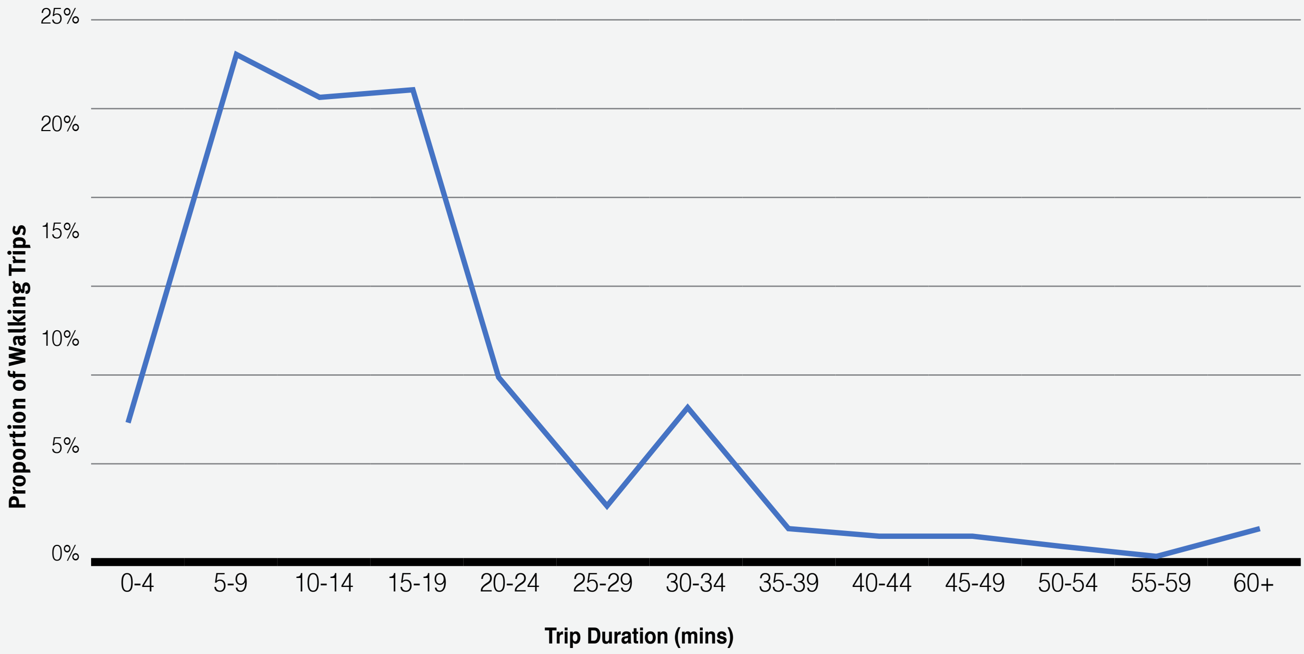
The majority of walking trips were less than two kilometres (88%) (Figure 10). However, analysis of walking trip duration (Figure 10) identified that there is a greater variance with the majority of walking trips (65%) lasting between 5 and 19 minutes.

The age and gender characteristics of those undertaking walking trips is shown in Table 17. The data indicates that females tend to make a higher number of walking trips compared to males, while the majority of trips were made by younger adults between the age of 16 and 39 years.

Table 17: Walking trip demographics (2014-2016)

Demographics		Frequency (n)	Percent (%)
Gender	**Males**	1,015,220	45.3
	Females	1,223,532	54.7
Age Group	**0-15yrs**	406,548	19.4
	16-39yrs	815,885	38.9
	40-59yrs	602,440	28.7
	60-69yrs	244,787	11.7
	70+yrs	169,093	8.1

Figure 10: VISTA 2014-16 Walking trips by duration



7.2 Incidence Rate Ratios

Incidence rates were calculated for combinations of exposure, measured using the VISTA travel surveys, and incidence, measured for the same time period using the police reported VPARS data. When considering incident and exposure corresponding with the most recent VISTA travel survey between 2014 and 2016.

Adjusting for population, male pedestrians had a higher relative risk (5%) of crash involvement compared to females, however the difference was not statistically significant (RR = 1.05 p = 0.18, CI [0.95, 1.17]). However, when considering number of trips (RR = 1.20 p = 0.00, CI [1.08, 1.34]) and distance (RR = 1.14 p = 0.00, CI [1.03, 1.27]) males were found to have a significantly higher risk of injury compared with females, 20% and 14% respectively.

When considering age groups, compared to pedestrians aged between 16 and 39 years, children (0 to 15yrs) had roughly half the risk of crash involvement when controlling for population (RR = 0.52 p = 0.00, CI [0.43, 0.63]), likewise adults aged 40 to 59 years (RR = 0.74 p = 0.00, CI [0.65, 0.86]) and 60 to 69 years (RR = 0.91 p = 0.16, CI [0.75, 1.1]) had lower relative risks of injury, however the difference was not statistically significant for the 60 to 69 year age group. Adults aged 70 years and older were increasingly likely to be injured as a pedestrian (RR = 1.6 p = 0.00, CI [1.37, 1.86]) when considering population, with the relative risk of injury similar for each population group when considering distance travelled and number of trips.

Time trend analysis between 2009 and 2014-16 indicated that the relative risk of injury decreased when considering population, number of trips and trip distance as exposure measures. This finding suggests that the risk of pedestrian injury at a population level is reducing across gender and age group. While reductions were identified for all age and gender combinations, it is noted that the lowest rates of reduction were observed for older pedestrians, when considering population as an exposure measure.

Table 18: Time trend analysis (Relative Risk [95% Confidence Interval])

Variables		Population	Trips	Distance
		VPARS	VPARS	VPARS
Gender	**Males**	0.72 [0.67, 0.77]	0.58 [0.61, 0.70]	0.48 [0.50, 0.58]
	Females	0.71 [0.64, 0.78]	0.57 [0.58, 0.70]	0.47 [0.48, 0.58]
Age Group	**0-15yrs**	0.73 [0.66, 0.81]	0.60 [0.60, 0.74]	0.49 [0.49, 0.60]
	16-39yrs	0.63 [0.52, 0.77]	0.66 [0.65, 0.97]	0.56 [0.56, 0.83]
	40-59yrs	0.65 [0.58, 0.73]	0.52 [0.56, 0.70]	0.42 [0.45, 0.55]
	60-69yrs	0.81 [0.69, 0.95]	0.52 [0.46, 0.63]	0.43 [0.37, 0.51]
	70+yrs	0.78 [0.61, 0.99]	0.65 [0.51, 0.83]	0.58 [0.46, 0.74]

8 Discussion

Pedestrians are one of the most vulnerable road user groups and the findings of this study highlight that significant numbers of pedestrian injuries occur within the road environment every year in Victoria. This demonstrates that substantial efforts are still needed to meet the Victorian Road Safety Strategies aspirational goals of Towards Zero 2016/2020 (Victorian Government) and new targets of Zero2050 (Strandroth et al. 2019).

Pedestrians involved in collisions are associated with a wide range of trauma, from minor injuries that are only reported to police, through to emergency department presentations, hospital admissions and a relatively small but substantial number of cases that result in death. One promising finding of this research is the reductions in Police-reported collisions and emergency department presentations over the ten-year study period. Furthermore, the number of hospital admissions remained relatively constant during this time, despite an overall increase in population across the state, indicating a per capita reduction in pedestrian trauma. However, road fatality data for 2019 indicates an increase in pedestrian trauma compared to 2018[1].

Concurrently, there has been an increase in the rate of walking trips being made across Victoria as evidenced through the findings of the Victorian Integrated Survey and Travel and Activity (VISTA) database. Combined, this has shown a reduction in the relative injury risk of walking at a population level. These are generally positive findings and with the benefits of increased walking well established (Badawi 2018), our findings highlight that, concurrent with promotion of active travel, there is a need for continued investment and improvements in the provision of safe walking environments to reduce the risk of injury.

While overall there has been a reduction in pedestrian trauma in Australia and other high income countries, as identified in the previous academic literature (Section 2), there are subgroups of pedestrians who remain at higher risk compared to the general population. The analysis in this report identified that older pedestrians, aged 70 years and older have the greatest risk of injury, roughly 1.6 times higher than young adults (16 to 39 years). This is consistent with previous research investigating pedestrian trauma in Victoria including O'Hern et al. (2015) and Senserrick et al. (2014), and consistent with international findings.

Older pedestrians are at increased risk for two general reasons: primarily, increased physical frailty and susceptibility to injury; and also a range of age related sensory, cognitive and physical impairments that might increase the risk of a crash, with even healthy adults experiencing some degree of decline throughout the ageing process (OECD 2001, Anstey et al. 2015). While the findings highlight that the relative risk for older adults has decreased, the risk has not reduced to the same extent as other age groups. It is also noted that Australia has an ageing population. Australians aged 70 years and older comprise a growing proportion of the total population, and this is projected to grow steadily over the coming decades (Australian Institute of Health & Welfare, 2018). In addition, it is noted that the profile of the older population is projected to change. In 2017, more than half of older people (57%, or 2.2 million) were aged 65-74 years, one-third were aged 75-84 years (30%, or 1.2 million), and 13 percent were aged 85 years and over. By 2047, it is projected that 65-74 year olds will comprise 45 percent of the older population, 75-84 year olds 35 percent, and 85+ year olds 20 percent. Furthermore, older Australians are living longer and in better health than ever before, and will have higher expectations for maintaining personal mobility (O'Hern et al. 2015). As such, more efforts need to be targeted towards improving walkability for older adults while reducing the disproportionate road trauma older pedestrians experience.

The other subgroup of high injury risk pedestrians identified in this study were young adults, particularly males. Injuries to young adults were particularly common at night and on weekends. Previous research has identified these as high alcohol times (Corben & Duarte, 2000) and identified that males are typically over-represented in alcohol-related pedestrian injuries. Alcohol slows brain function, reduces judgement and increases risk taking behaviours. It can also affect sense of balance making pedestrians unsteady on their feet and less capable of performing tasks such as crossing the road. There is evidence that high BAC levels are associated with increased risk of injury, and associated with poorer road crossing decisions (Oxley et al. 2006, Dultz et al. 2011, Eichelberger et al. 2018). Clearly there is a need to address pedestrian and motor vehicle interactions in locations where there are high volumes of pedestrians and licenced venues. During high alcohol times, it is unlikely that the road network is required to cater for peak volumes of motor vehicle traffic.

[1] http://www.tac.vic.gov.au/road-safety/statistics/lives-lost-year-to-date

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As such, measures to reduce vehicle speeds and increase pedestrian priority could be applied to reduce the risk of injury without a substantial impact on vehicle movement. Street lighting was also identified as a potential issue that may help to reduce the risk of collisions at night time, with 11 percent of crashes that occur while it is dark occurring in locations with no street lighting.

In general, males were also over-represented at all levels of pedestrian trauma, however in some instances the differences were not statistically significant. The findings are also supported by previous Australian studies that have identified gender differences. For example in the previous research Senserrick et al. (2014) identified a similar gender bias and recommended that educational initiatives that focus on promoting safe crossing behaviours may be an appropriate method for reducing trauma, particularly amongst younger males, who are more likely to engage in risky crossing manoeuvres.

Not surprisingly, speed environment was a major factor identified in the research. When considering pedestrian crashes as a whole, the majority were found to occur in urban areas, with the highest proportion of crashes occurring in 60 km/h speed zones. This finding suggests that minor arterial roads represent a significant concern for pedestrian safety. This is likely due to the increased integration of pedestrians and motor vehicles in these lower speed arterial environments. However, there was a significant association between injury outcome and higher speeds. This finding confirms the increased risk for pedestrians when interacting with vehicles in environments where the speed limit is 50 km/h or above. While it is noted that estimates of vehicle travel speed are not recorded in the datasets, the posted speed limits are an indication of general travel speeds.

The spatial analysis undertaken in this report indicated clusters of pedestrian crashes in areas with high numbers of pedestrians, in these locations it would be appropriate to also consider reducing speed limits on the arterial road network. This may help to alleviate some of the risk to pedestrians, particularly in areas currently posted with 60 km/h speed limits.

When considering the characteristics of vehicles involved in collisions with pedestrians, the research confirmed that the vast majority of pedestrian injuries resulted due to collisions with cars and other light vehicles, reflecting their dominance of the vehicle fleet.

The findings highlight a need to emphasise pedestrian safety amongst motorists, particularly in areas with high concentrations of pedestrians including the Melbourne CBD, and major urban and regional centres. The crash statistics presented in this report demonstrate the disproportionate number of crashes occurring in highly pedestrianised areas. In these locations there is clearly a need to prioritise pedestrians over motorised modes of transportation. This can be achieved through:

- A reallocation of priority away from motorised modes and a reallocation of space towards increased pedestrian activity;
- Reduced speed limits and street design for lower speed; and
- Enforcement strategies that discourage dangerous driver behaviours to target aberrant behaviours when interacting with vulnerable road users.

The findings suggest that some driver characteristics may contribute to increased pedestrian collision risk including the presence of alcohol and distraction through mobile phone use. There were also an alarming number of collisions coded as a hit and run. Furthermore, the driver was identified as offending in 46.4 percent of cases, and up to 64.5 percent of crashes. This indicates that improved driver behaviours could substantially reduce the burden of injury to pedestrians. These findings support previous findings of an increased risk due to driver distraction and poor performance (Chong et al. 2018, Dong et al. 2019).

Notwithstanding the high number of offending drivers, there were 35.5 percent of cases where the driver was not classified as offending. It is possible that in some of these cases pedestrian behaviours may have been a contributing factor. While this research cannot ascertain if this is the case, there is a need to further understand pedestrian behaviours to identify the proportion of pedestrians who may be engaging in risky behaviours and if needed develop targeted interventions to improve pedestrian safety.

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While the datasets provide limited information regarding pedestrian behaviour at the time of collisions, what can be ascertained is that the majority of crashes occur when pedestrians are crossing the carriageway. Furthermore, there was a high proportion of collisions involving motor vehicles during turning movements, particularly right turning vehicles. The issue at intersections is further highlighted with roughly half of all pedestrian collisions reported in the vicinity of an intersection. Clearly the findings indicate a need to improve pedestrian safety at intersections.

At intersections drivers are required to give way to pedestrians crossing the street they are turning into, with the exception of a roundabout. However drivers are not required to give way to pedestrians crossing in front of them, even at a stop or give way sign. This is counter-intuitive and makes the give way rules at intersections complicated.

VicRoads are currently increasing the number of fully controlled right turn intersections in an effort to improve road user safety at intersections. Other treatments intended to improve pedestrian safety include partially controlled turns, early starts for pedestrians, exclusive pedestrian phases and in highly pedestrianised zones reconfiguring the priority at intersections to provide for pedestrians ahead of motorists. Threshold treatments, raised platforms and other design measures may also be appropriate in lower speed environments as a traffic calming measure for motorists. Furthermore it is essential that gaps in the walking network are identified and that adequate crossing locations are provided to ensure that long distances between crossing opportunities are minimised, as this can create unsafe pedestrian crossing conditions, especially for more vulnerable pedestrians such as seniors and those with a disability.

It is important to also note that pedestrian trauma is an issue outside of Melbourne and the research identified relatively high incidence rates in key regional centres including Geelong, Ballarat, Bendigo, Shepparton and in the Latrobe Valley. Regional centres in Victoria typically have higher proportions of older adults and addressing pedestrian road safety issues in these regions may substantially reduce the over-representation of older pedestrians. The findings highlight that pedestrian safety is a state-wide issue and that needs to be addressed through a coordinated approach between state and local government and other key stakeholders.

8.1 Limitations

It is noted that there are several limitations with the analyses conducted in this study. The study has relied on a range of datasets, each with their own priorities and methods for data collection and dissemination.

The VPARS dataset provides a link between police reported cases and TAC claims data. While this provides a rich dataset particularly regarding the circumstances of the crash, it does not include information on the exact nature or severity of the injuries. Furthermore a noted issue with many police reported datasets both in Australia and Internationally is under-reporting (Sciortino et al. (2005); Lopez et al. (2000), Alsop & Langley (2001), Rosman (2001), particularly regarding vulnerable road users and collisions that result in minor or no injuries. Furthermore, while the dataset provides some insight into the causal factors of collisions, there is only limited information regarding the pedestrian and driver actions and behaviours immediately preceding the incident that may have contributed to the collision. There are also noted limitations with the use of some of the codes in the dataset, for example the current DCA codes provide limited information regarding pedestrian and vehicle movements, preceding the collision.

Regarding the VISU and COD-URF data, only de-identified aggregate data was available for analysis and this limits the type of analysis that could be undertaken. It is also acknowledged that there are few adequate data sources available to understand active travel trends and there are some noted limitations of the data used in this analysis of pedestrian exposure. Furthermore, this study has utilised an ecological study design, which has only considered relationships at the population level and there are limitations with the use of registration data as not all vehicles types have been captured in the analysis.

Ecological studies are subject to ecological fallacy and further individual level data would be required to provide a more comprehensive understanding of road safety issues for pedestrians. Furthermore, a potential limitation with the use of household travel survey data is that certain walking trips are under-reported, particularly trips undertaken by children which are generally recorded by the adults undertaking the survey, as such there is the potential for under-reporting of walking trips in the dataset. Furthermore, the analysis has only considered walking trips, while many trips undertaken using other modes will also incorporate walking components.

8.2 Future Research

The findings of this research highlight the need for continued improvements in the collection of pedestrian data. The linked police and TAC dataset provides valuable insight into the factors associated with pedestrian collisions, however there is scope for more detailed crash investigation through the use of in-depth studies, where injured pedestrians are recruited and interviewed to obtain a more comprehensive understanding of the causal factors and injury outcomes associated with crashes.

Observational studies or surveys of the pedestrian population would provide valuable insight into issues surrounding pedestrian and road user distraction and behaviours. Naturalistic studies of driver behaviours have proven to provide valuable information regarding driver behaviour (Young et al. 2019). Similar observation study methodologies have been implemented to understand pedestrian behaviour (Horberry et al. 2019), however further research is warranted.

It is clear from the research that there is still a need for improved infrastructure for pedestrians. In terms of further research, this may include reviewing existing Australian design guidelines, evaluations of new and innovative road infrastructure treatments as well as the need for road safety audits to identify safety issues within the road and roadside environment.

A key deficiency identified in this research and previously noted, is the need for accurate measures of exposure when assessing road safety improvements. Currently in Victoria there is limited information available regarding the number and duration of walking trips. While the VISTA travel survey provides an indication, enhanced measures of exposure allow for most accurate and meaningful comparisons to be made and allow for more accurate monitoring to occur over time. These recommendations would ideally be coordinated within a walking strategy for Victoria, which would provide a central reference point for strategically addressing pedestrian issues and encouraging increased safer walking.

8.3 Recommendations

In line with the Victorian road safety strategy, Toward Zero 2016/2020 (Victorian Government) and new targets of Zero2050 (Strandroth et al., 2019), there is a growing realisation that the needs for the most vulnerable road users should be prioritised. Pedestrian safety is at the core of providing safe and accessible environments for vulnerable road users, and it is important that a comprehensive, holistic approach is adopted that includes engineering, legislation, enforcement and behavioural measures (including promotion of active travel).

Within the Safe System pillars, a number of initiatives and efforts are recommended below that have the potential to achieve substantial reductions in the incidence and severity of on-road pedestrian deaths and serious injuries in Victoria.

8.3.1 Safer Speeds and Safer Roads

Efforts to lower vehicle speeds in areas where there is a mix of pedestrians, vehicles and other road users is a critical step to address pedestrian safety. Ideally when pedestrians and motorised vehicles interact traffic speeds should be reduced to a level that, in the event of a collision, would not result in a serious injury to the pedestrian. While research suggests that this threshold is 40 km/h for an adult interacting with a light vehicle, best practice suggests that 30 km/h speed limits are preferred (ITF/OECD 2018, Corben 2020).

As noted by Corben (2020), 30 km/h speed limits in local streets offer the simplest and lowest cost means of designing for Safe System risk levels for pedestrians and cyclists. However, with the current default urban speed limit of 50 km/h, a move to more widespread 40 km/h limits would still be a step in the right direction. Even at 40 km/h, significant investment in infrastructure would ideally accompany reduced speed limits to secure travel speeds in local streets to genuinely low risk levels for pedestrians and cyclists. There has been long-standing discussion and debate about the long-term effectiveness of introducing lower speed limits in local streets (i.e., below the 50 km/h urban default) without also constructing supporting traffic-calming infrastructure.

In addition to lowering vehicle speeds, treatments that provide separation of travel modes and aligned with Safe System principles have shown promise in reducing exposure to risk and reduced pedestrian fatalities and serious injuries. Such treatments include: pedestrian priority areas; footpaths; smart and conspicuous crossing facilities; refuge islands and raised medians; and removal of slip lanes.

Additional treatments that achieve improved sight distance and/or visibility between drivers and pedestrians include: enhancements to crossing facilities including raised crosswalks, improved lighting at crosswalks and intersections and kerb extensions.

Recommendations include:

- Reductions in speed limits, including to 30 km/h in areas of high pedestrian activity and residential streets;
- Speed limit reductions are supported with appropriate traffic calming infrastructure to ensure drivers and riders are compliant with speed limits;
- Provision of more pedestrian oriented developments (pedestrian prioritisation);
- Implementation of Safe System aligned treatments to separate vulnerable road users and vehicles and create safer crossing points;
- Implementation of Safe System aligned treatments to improve sight distance and visibility of pedestrians;
- Provision of safe, convenient and direct walking routes to minimise the need for risky walking behaviours; and
- An ongoing program of state government investment to deliver these improvements.

8.3.2 Safer Vehicles

There have been substantial improvements in vehicle design, occupant protection features and rapid development of safety features that have the potential to reduce the incidence and severity of pedestrian collisions. Some vehicle technologies (active safety features) can assist in collision avoidance or reducing impact speed, principally through alerts and/or speed reduction through brake-assist or autonomous braking systems, forward collision warning systems, intelligent speed adaptation systems, rear-facing cameras and warning systems, and night enhanced vision systems. These systems can reduce severity or prevent pedestrian injuries regardless of the vehicle type and specific body region. Other vehicle design features and technologies are designed to minimise pedestrian injury in the event of a collision. These systems include enhanced frontal and bumper designs, particularly changes in the shape and the stiffness of vehicle frontal structures, provision of pedestrian airbags, increasing the crush depth between the outer surface of the vehicle and hard objects underneath (such as engine parts), and also by modifying the stiffness of the vehicle's structure below the outer surface so that in an impact it absorbs as much energy as possible without causing injury. ANCAP testing now includes tests for pedestrian protection.

The deployment of new vehicle technologies has the potential to yield a new wave of road safety and other benefits and can play a key role in managing the safety of pedestrians. Recommendations include:

- Development of programs and initiatives to address improved uptake and awareness of safer vehicles (e.g., targeted education campaign on safe vehicle purchase and use; providing financial or other incentives for purchasing safer vehicles);
- Enhance and further promote existing information and resources such as www.howsafeisyourcar.com.au, www.ancap.com.au, used car safety rating guides; and
- Further development of technologies to assist with detection of pedestrians and crash avoidance.

8.3.3 Safer Road Users

Effective behavioural, educational and training programs can be integrated with and support speed reduction, road design and vehicle safety improvements and are essential components of an aspirational Safe System. Concurrent initiatives to promote active travel and walkable communities are essential, and programs should be targeted for particular vulnerable groups.

Recommendations include:

- For drivers, develop educational and training programs addressing pedestrian safety and adoption of safer driving practices and enforcement of lawful driving;
- Support national efforts to promote walking and walkable communities through health promotion campaigns;
- For older pedestrians, development and implementation of education and behavioural programs providing information on schemes and initiatives to support and promote active travel, technologies and other media to provide active travel information.;
- For children, development and implementation of educational and training programs promoting safe active travel co-ordination with schools, parents and councils to provide safety around school environments; and
- For young adults, development of programs addressing alcohol and drug use and walking, alongside measures to manage the road environment around alcohol venues.

8.4 Conclusions

This study employed analyses of multiple injury register datasets to develop a comprehensive understanding of the issues and factors associated with pedestrian injury across all levels of trauma in Victoria. The findings demonstrated that there was an encouraging increase in walking amongst Victorians, however, pedestrian trauma remained substantial, and high-risk groups included older and young adults. Clusters of pedestrian collisions were identified in urban high pedestrian activity areas and in speed zones of 60 km/h. The findings also suggested that drivers were often either alcohol-impaired or distracted, and there was a substantial proportion of hit and run events. Recommendations centre around implementation of Safe System principles and include reductions of vehicle speeds in high pedestrian activity areas and supporting road infrastructure, promotion of safer vehicles, and development and implementation of educational and training programs for young pedestrian groups, particularly those engaging in ‘drink walking’, and drivers.

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