# Safer road crossings for pedestrians including older pedestrians, and pedestrians with disabilities

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Abstract
The aim of this literature review was to identify options to improve the safety of crossing roads by pedestrians in Western Australia (WA), including those at most risk such as older people and those with disabilities. Literature was sourced from journals, government documents, conference papers, Main Roads WA guidelines, Australian Standards and safety websites. Part 1 of the review identified common difficulties experienced by older pedestrians and those with disabilities when crossing the road. Part 2 described the current pedestrian crossing options used in WA and reported that the safest options for vulnerable pedestrians were Puffin crossings at mid-blocks and parallel crossings with full protection as well as count down timers at signalised intersections. Part 3 described several alternative pedestrian crossing options and recommended those which may be beneficial to trial in WA for vulnerable pedestrians. These included speed humps, flashing beacons, additional signage or vehicle stop lines on approach to zebra crossings. In addition, trialling pedestrian detection or swipe card technology which can extend the pedestrian crossing phase was recommended at signalised intersections.



Keywords
Older pedestrians, pedestrians with disabilities, road crossing safety, pedestrian technology

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## Introduction, aims and objectives

Both pedestrians and older road users have been identified as high priority categories in the *"Towards Zero"* road safety strategy for Western Australia (WA). Ageing can result in increased risk of involvement in pedestrian crashes and more severe injury in the event of a crash. Pedestrians of any age who have disabilities are another particularly vulnerable group and one in five Australians have some form of disability. Older pedestrians and those with disabilities may have particular difficulty crossing roads due to mobility issues, cognitive decline and reduced reaction times. Improving existing pedestrian crossing facilities or constructing new facilities will play an important role in reducing crashes among vulnerable pedestrians. Therefore, this project aimed to identify options to improve the safety of crossing roads by pedestrians in Western Australia, including those at most risk such as older adults and those with disabilities..

The specific objectives were to:

1. Search published, peer-reviewed and grey literature for safe crossing options for pedestrians, specifically older pedestrians, and pedestrians with disabilities.
2. Identify evidence of the relative effectiveness and appropriateness of these safe crossing options.
3. Identify the best options for safe crossing for pedestrians.

## Methods

Multiple sources were used to undertake the literature review from 1980 to 2018. These included peer-reviewed journal articles, grey literature including government reports and documents, technical reports, conference papers, guidelines and standards documents produced by Main Roads WA and Austroads, Australian Standards, road safety websites and the websites of pedestrian crossing technology developers. The literature was obtained by searching Google, Google Scholar, ResearchGate and various library databases including ScienceDirect, Web of Science, ProQuest and PubMed. The search terms used included the following: *"pedestrian safety", "older pedestrians", "pedestrians with disabilities", "road crossing technology" and "pedestrian road safety treatments".* Furthermore, other relevant publications of authors who had published widely in the area or had a significant publication relevant to the topic, and publications cited by relevant articles were also reviewed.

## Literature review

### *Part 1: Safety issues for older pedestrians and those with disabilities*

Part 1 of the literature review identified issues experienced by older pedestrians and those with disabilities, related to crossing the road. Difficulties or characteristics were very similar for older people and those with a variety of disabilities. These included:

- A desire to take the shortest route, even if it is not the safest;
- Willingness to wait longer to cross at traffic lights and higher compliance with signals than other pedestrians;
- Slower walking/ travelling speeds across the road;
- Difficulty with gap selection especially in complex environments, in higher traffic volumes and when the approaching vehicle speed is high;
- Risk of near-side and far-side crashes, depending on type of disability;
- Poor visibility of wheelchair and mobility scooter users for motorists.

In addition, common characteristics of pedestrian crashes involving older pedestrians were: pedestrian crossing the road, near side lane crashes, speed limits of 50 or 60 km/h, daylight hours, arterial shopping precincts and complex road environments.

### *Part 2: Pedestrian crossing options in WA: current situation*

Part 2 described the current pedestrian crossing options used in WA at mid-blocks, signalised intersections, un-signalised intersections, roundabouts and other locations. It also reviewed evidence on the safety of each of these existing options for older pedestrians and those with disabilities.

At mid-blocks, Puffin crossings, followed by Pelican crossings (both signalised) provide the safest options for older pedestrians and those with disabilities. On certain roads, pedestrian refuges or zebra/ wombat crossings may also provide safe options. Raised medians and painted medians are not suitable solutions for these vulnerable pedestrians.

At signalised intersections, parallel crossings with full protection by vehicle signals provide a high level of protection for this group as they do not have to watch for turning vehicles. It is likely that exclusive phasing would also be a safe option for vulnerable pedestrians, but this type of phasing is not favourable for other pedestrians and motorists.

Pedestrian signal timing in WA is generally based on a walking speed of 1.2 m/s but 1.0 m/s can be used for slower moving pedestrians. Evidence indicates that a crossing time based on 1.2 m/s would be inadequate for many older adults to cross the whole road and 1.0 m/s would be insufficient for pedestrians aged 80+. Extending pedestrian phases or use of technology that detects pedestrians who remain in the intersection and extends the crossing time, could increase safety for older pedestrians and those with disabilities.

Pedestrian countdown timers at signalised intersections may have a positive effect on safety for older pedestrians and those with a disability. This is due to increased signal compliance by assisting them in making a decision about whether it is safe to begin a road crossing. Main Roads WA plan to continue installing the timers at WA intersections. Targeting areas with larger numbers of older pedestrians or those with disabilities could improve pedestrian safety outcomes.

In areas of high pedestrian activity, particularly complex environments with a high volume of mixed road users, reduced speed limits, variable speed limits, traffic calming and reduced traffic volumes could also be highly effective in reducing crashes and crash severity among older pedestrians and those with disabilities.

***Part 3: Alternative crossing options for pedestrians***

Part 3 described several pedestrian crossing options that are used in other countries or are new, emerging options. Where available, evidence of their effectiveness was provided.

Options that are currently available and may be useful for older pedestrians and those with disabilities in WA included:

- Speed humps on approach to zebra crossings at mid-blocks. These are used in Europe to reduce vehicle speeds.
- Use of additional lights, signage and vehicle stop lines at mid-block zebra crossings. These are used at Rectangular Rapid Flashing Beacon (RRFB) crossings in North America to increase the visibility of the crossing and driver compliance with pedestrian right of way.

- SafeWalk and C-Walk pedestrian detection systems at signalised intersections. These video detection systems can detect pedestrians waiting to cross as well as those who remain on the crossing and extend the pedestrian phase as required.
- A *"Green Man"* type scheme at signalised intersections, like in Singapore. This extends the pedestrian crossing phase by a set amount if time if an older pedestrian or pedestrian with a disability scans their card.

Several of the options reviewed are not currently commercially available but could be useful for older pedestrians and those with disabilities in the future including:

- Starling Crossings at mid-blocks which involve a responsive surface laid on the road which can detect pedestrians and modify road markings using LED lights.
- On-person crossing technology such as vibrotactile wristbands and the ZebraRecognizer mobile phone app which assist with road crossing.

Options that are unlikely to improve safety for vulnerable pedestrians include:

- In-ground pedestrian lights at signalised intersections which are connected to the traffic lights and shine the same colour as the pedestrian crossing signals.
- Pedestrian switch pads at signalised intersections which are pressure-sensitive tactile pads that detect pedestrians when stood on and modify traffic signals.

**Conclusion and recommendations**

Recommendations were made for the continued use of specific existing crossing options, further research and the types of alternative pedestrian crossing options that would be useful to trial in WA. This encompasses Phase 1 of the project. The proposed Phase 2 of the project would involve identifying a suitable Local Government Association (LGA) to trial the alternative options, selecting appropriate trial sites and evaluating the effectiveness of the crossing option in terms of improving road safety for pedestrians, focusing on older pedestrians and those with disabilities.

***Existing pedestrian crossing options in WA***

- Recommendation 1: Continued implementation of existing safe pedestrian crossing options at mid-block locations including Puffin crossings, zebra or wombat crossings and pedestrian refuges, as appropriate.

- Recommendation 2: Continued implementation of existing safe pedestrian crossing options at signalised intersections including parallel pedestrian crossing phasing with full protection by vehicle signals and countdown timers.
- Recommendation 3: Continued implementation of existing strategies to improve pedestrian safety along sections of road which have complex traffic environments including lower speed limits, variable speed limits, traffic calming and traffic volume reduction methods.

***Further research***

- Recommendation 4: Conduct further research into whether current pedestrian signal phase timing in WA is adequate for older pedestrians and those with disabilities to safety complete the road crossing at signalised intersections and signalised pedestrian crossings.

***Alternative pedestrian crossing options***

- Recommendation 5: Trial and evaluate the effectiveness of providing additional treatments at zebra or wombat crossings located at mid-blocks. These treatments include speed humps on approach to the crossing, flashing beacons, additional signage for vehicles and vehicle stop lines.
- Recommendation 6: Trial and evaluate the effectiveness of providing additional treatments at signalised intersections. These include pedestrian detection technology (e.g. SafeWalk/ C-Walk) which can extend the pedestrian crossing phase as required and swipe card technology (e.g. The *"Green Man"* Scheme) which can extend the pedestrian phase by a set amount of time.

# 1 INTRODUCTION

The older adult population is growing faster than any other age group (Department of Economic and Social Affairs: Population Division, 2006). In 2012, people aged 65+ and 85+ years made up 14% and 2% respectively of the Australian population and this is projected to increase to 22% and 5% by 2061 (Australian Bureau of Statistics, 2013). Walking is an important activity for older adults increasing their health, independence and quality of life (Jancey et al., 2013). Ageing however, can result in increased risk of involvement in pedestrian crashes and more severe injury in the event of a crash (O'Hern, Oxley, & Logan, 2015). Pedestrians of any age who have disabilities are another particularly vulnerable group and over 4 million Australians (1 in 5) have some form of disability (Australian Bureau of Statistics, 2016).

The *"Walk WA"* strategy (2007-2020) developed by the Premier's Physical Activity Taskforce and the Department of Planning and Infrastructure recognises the health, transport and environmental benefits of supporting more people to walk in Western Australia (WA) and aims to increase the proportion of adults who report walking as well as the number of walking trips per adult per week (Premier's Physical Activity Taskforce, 2007). Increased walking however, means more exposure to traffic and increased risk of pedestrian crashes among vulnerable groups if pedestrian facilities are inadequate (Pucher & Dijkstra, 2003). Older pedestrians and those with disabilities may have difficulty crossing roads due to mobility issues, cognitive decline and reduced reaction times (Tournier, Dommes, & Cavallo, 2016). Improving existing pedestrian crossing facilities or constructing new facilities will play an important role in safely achieving the *"Walk WA"* targets and reducing crashes among vulnerable pedestrians.

Both pedestrians and older road users were identified as high priority categories in the *"Towards Zero"* road safety strategy for WA (Office of Road Safety, 2009). Therefore, this literature review will identify options to improve the safety of crossing roads by pedestrians in WA, including those at most risk such as older people and those with disabilities. This project involves two pillars of the Safe System identified in the Toward Zero strategy: safe road use and safe roads and roadsides. Phase One of this project consists of the literature review presented in this report. It reviews current technology available to enhance the safety of pedestrians engaging with the transport system, particularly at intersections and areas with a high volume of mixed road users, with a focus on older pedestrians and those with disabilities. Phase Two will take place at a later date and will involve a Perth-based trial of pedestrian technology for vulnerable pedestrians. By identifying options to improve the safety of crossing roads by older pedestrians in WA, this project will ultimately improve the safety of older road users.

## 1.1 AIMS AND OBJECTIVES

This project aims to identify options to improve the safety of crossing roads by pedestrians in Western Australia, including those at most risk such as older people and those with disabilities.

The specific objectives of phase one are to:

1. Search published, peer-reviewed and grey literature for safe crossing options for pedestrians, specifically older pedestrians, and pedestrians with disabilities.
2. Identify evidence of the relative effectiveness and appropriateness of these safe crossing options.
3. Identify the best options for safe crossing for pedestrians.

# 2 METHODS

Multiple sources were used to undertake the literature review from 1980 to 2018. These included published, peer-reviewed journal articles, grey literature including government reports and documents, technical reports and conference papers, guidelines and standards documents produced by Main Roads WA and Austroads, Australian Standards, road safety websites and pedestrian crossing technology developer websites.

Grey and peer-reviewed literature was obtained by searching Google, Google Scholar, ResearchGate and various library databases including ScienceDirect, Web of Science, ProQuest and PubMed. The search terms used included the following: *"pedestrian safety", "older pedestrians", "pedestrians with disabilities", "road crossing technology"* and *"pedestrian road safety treatments"*. Furthermore, other relevant publications of authors who had published widely in the area or had a significant publication relevant to the topic, and publications cited by relevant articles were also reviewed.

This report uses *'person-first'* language to describe people with a disability, i.e. *'people with a disability'* rather than *'disabled people'*, as recommended by the American Psychological Association. This language identifies the person with a disability as a person first, rather than identifying them by their disability and avoids the implication that the person as a whole is disabled (American Psychological Association, 2019)

# 3 LITERATURE REVIEW

This literature review is divided into three sections.

- Part 1 reviews the specific safety issues/ difficulties related to road crossing for older pedestrians and those with disabilities.
- Part 2 describes the current pedestrian crossing options used in WA and existing evidence on the safety of these options for older pedestrians and those with disabilities.
- Part 3 reviews pedestrian crossing options that are used in other countries or are new, emerging options.

## 3.1 PART 1: SAFETY ISSUES FOR OLDER PEDESTRIANS AND THOSE WITH DISABILITIES

### 3.1.1 Pedestrian safety in WA

A pedestrian is any person on foot, in a pram, or a person with disability in an un-motorised or motorised wheelchair ("Western australia road traffic code," 2000). In WA in 2017, 15 pedestrians were killed on the roads (0.6 deaths per 100,000 population), with the preceding five-year average being 14. The majority of these crashes occurred in metropolitan area (67%) and five pedestrians (33.3%) were aged 80 years or older (5.8 deaths per 100,000 population) (Road Safety Commission, 2017). The most recent available hospital inpatient statistics report that in 2014, 278 pedestrians aged 60+ were also hospitalised due to a crash in WA (Road Safety Commission, 2016).

A recent study of pedestrian injuries in Victoria between 2003 and 2012 similarly found that adults over 65 years were involved in 21% of all pedestrian crashes with high fatality rates for those aged 75 years and older (3.2 deaths per 100,000 population), compared to adults aged less that 65 years (0.7 deaths per 100,000) (O'Hern et al., 2015). This over-representation of older pedestrians in fatal and serious injuries is reflected in other OECD countries with people aged 65 years and older representing 13-20% the population in these countries but over 50% of pedestrian fatalities (International Transport Forum, 2012). Specific information on the characteristics of older pedestrian crashes has not been published in WA. In an analysis of pedestrian crashes in the Perth central business district (CBD) from 2008-2012, only 6.6% of the pedestrians involved were aged 60+ (Palamara & Broughton, 2013). This does not reflect the overall proportion of older adults involved in pedestrian crashes in Perth as they may be less likely to be in the CBD area compared to younger adults of employment age.

Pedestrians of any age who have disabilities are another particularly vulnerable group. A disability is defined as *"any condition that restricts a person's mental, sensory or mobility functions. It may be caused by accident, trauma, genetics or disease. A disability may be temporary or permanent, total or partial, lifelong or acquired, visible or invisible"* (Australian Network on Disability, 2018). Over 4 million Australians (1 in 5) have some form of disability. The likelihood of disability increases with age with two in five of those living with a disability being aged 65+, compared to one in eight aged under 65 years (Australian Bureau of Statistics, 2016). Extremely limited statistics or published studies exist which specifically examine safety issues for pedestrians with disabilities. However, since many pedestrians with disabilities are also of an older age and it is likely that pedestrian crossing treatments which improve safety for older adults would also improve safety for pedestrians with disabilities of any age.

### 3.1.2 Functional changes in older adults and pedestrian safety

The normal ageing process may affect pedestrian safety in many ways. Functional changes in older adults may increase the risk of involvement in a pedestrian crash, while frailty increases the risk of being killed or seriously injured in the event of a crash (Tournier et al., 2016). Tournier et al. provided in in-depth review of functional changes in older adults and how these may affect pedestrian safety (Tournier et al., 2016). The main points from this review as well as information from other sources are summarised below.

#### *3.1.2.1 Visual impairment*

Declines in vision and visual conditions of ageing may affect walking and road crossing ability (Tournier et al., 2016). For example, reduced visual acuity (clarity of vision) is associated with difficulty discriminating vehicles from the rest of the road environment (Oxley, Fildes, Ihsen, Day, & Charlton, 1995). Reduced contrast sensitivity (ability to perceive differences between an object and its background) has been associated with reduced perception of both fixed and moving vehicles (Oxley et al., 1995). In addition, decline of visual motion sensitivity with age can affect the ability to judge the speed of an approaching vehicle (especially high-speed vehicles), leading to unsafe crossing decisions (Dommes, Cavallo, & Oxley, 2013; Snowden & Kavanagh, 2006).

#### *3.1.2.2 Hearing impairment*

Hearing loss increases with ageing (Salonen, Johansson, Karjalainen, Vahlberg, & Isoaho, 2011), however there are very few studies investigating the impact on pedestrian safety.

Hearing may help with the detection of vehicles coming from behind or turning (Dunbar, Holland, & Maylor, 2004). One study reported that diminished hearing is associated with riskier street-crossing decisions in older pedestrians (Rodrigues, Pinto, Dommes, Cavallo, & Vienne, 2012).

#### *3.1.2.3 Proprioceptive and vestibular system impairments*

The proprioceptive and vestibular systems assist in standing upright and moving through space (Tournier et al., 2016). Age-related proprioceptive and vestibular declines can lead to impaired sense of balance and risk of falling (Gauchard, Jeandel, & Perrin, 2001; Patel, Fransson, Karlberg, Malmstrom, & Magnusson, 2010). This may increase the risk of unsafe road crossing due to slower speed and poorer balance when walking (Tournier et al., 2016).

#### *3.1.2.4 Cognitive impairment*

Ageing is associated with declines in processing speed, or the rate at which the brain and nervous system can process sensory information (Tournier et al., 2016). Processing speed has a strong impact on the ability to make safe road crossing decisions (Tournier et al., 2016). In addition a decline in shifting skills (the ability to switch lines of reasoning and actions in order to perceive, process and respond to situations in a flexible way) have shown to be a significant predictor of street-crossing collisions (Dommes et al., 2013). For example, older pedestrians with poor shifting skills have more difficulty switching their attention between traffic approaching from two different directions and selecting the most relevant information (Dommes et al., 2013).

#### *3.1.2.5 Physical impairment*

Physical declines are also common with ageing (Tournier et al., 2016). A decline in muscle strength is associated with slower walking and an increased risk of falling (Asher, Aresu, Falaschetti, & Mindell, 2012; Landi et al., 2012). Low bone mineral density associated with osteoporosis increases with ageing is associated with difficulty walking, poor postural control, risk of falling and increased risk of fracture (Katzman, Vittinghoff, Ensrud, Black, & Kado, 2011).

#### *3.1.2.6 Self-awareness and self-regulation*

Self-perception of reduced functional abilities with age is an important factor in pedestrian safety and older adults can adjust their behaviour to match their abilities (Tournier et al., 2016). However, studies have found that older adults often underestimate the time they need to cross the street, impacting on safety (Naveteur, Delzenne, Sockeel, Watelain, & Dupuy, 2013; Zivotofsky, Eldror, Mandel, & Rosenbloom, 2012).

### 3.1.3 Road crossing among older pedestrians: current research

The road crossing task is complex requiring several steps. These include selecting a crossing location, checking for oncoming vehicles or traffic light signals, selecting a safe time to cross by judging gaps in the traffic, assessing the amount of time available for crossing and adjusting walking/ travel speed to account for approaching traffic (Tournier et al., 2016). Older pedestrians may experience slower walking speeds as well as difficulties with gap selection. These issues are described below.

#### *3.1.3.1 Use of pedestrian crossing facilities*

Pedestrian crosswalks and signals reduce the need for gap selection. It has been found that older, compared to younger pedestrians reported that they preferred to use these facilities (Bernhoft & Carstensen, 2008). Most studies have also indicated that older pedestrians are willing to wait longer to cross at traffic light signals (Guo, Gao, Yang, & Jiang, 2011; Paschalidis, Politis, Basbas, & Lambrianidou, 2016) and are less likely to violate these signals (Dommes, Granie, Cloutier, Coquelet, & Huguenin-Richard, 2015; Granié, Pannetier, & Guého, 2013; Ren, Zhou, Wang, & Zhang, 2011; Rosenbloom, Nemrodov, & Barkan, 2004), than younger pedestrians. However, older pedestrians also reported regularly crossing the road at their current location where these facilities were not available (Bernhoft & Carstensen, 2008). When these facilities are located too far away or in an inconvenient location, pedestrians with physical impairments, reduced mobility or poor health, will likely choose to take the shortest route, even if it means crossing the road at an unsafe location. It is likely that these findings would apply also pedestrians with various disabilities.

#### *3.1.3.2 Gap selection*

Several studies using simulated road crossing tasks have reported that older pedestrians have greater difficulty selecting safe gaps when crossing the road (Dommes & Cavallo, 2011; Dommes, Cavallo, Dubuisson, Tournier, & Vienne, 2014; Oxley, Ihsen, Fildes, Charlton, & Day, 2005). However, when traffic is light, the gap selection and crossing behaviour of older and younger pedestrians is reported to be very similar (Dunbar et al., 2004). When traffic is heavier and the crossing environment more complex, older pedestrians make more risky crossing decisions (Dunbar et al., 2004). This is likely related to reduced information processing ability (Tournier et al., 2016). Two studies reported that the older pedestrians accepted shorter and shorter time gaps as the approaching vehicle's speed increased whereas younger people were more able to accurately judge the speed of approaching vehicles and modify their crossing behaviour accordingly (Dommes & Cavallo, 2011; Oxley et al., 2005). A further study also found that some older pedestrians based their decisions mainly on the gap available in the near lane, while neglecting the far lane, putting them at risk of a far side crash (Dommes et al., 2014).

#### *3.1.3.3 Speed of road crossing*

Older pedestrians and those with disabilities may walk slower than the general population (Tournier et al., 2016) due to shorter stride lengths, more time spent with both feet on the ground and bent posture (Salzman, 2010; Winter, Patla, Frank, & Walt, 1990). In addition, older pedestrians and those with disabilities who use walking aides such as canes or walking frames or use wheelchairs, move more slowly when crossing the road (Tournier et al., 2016). Acceleration capacity or the ability to increase speed and stride length has also shown to decrease with age (Buckley, Pitsikoulis, Barthelemy, & Hass, 2009). Walking speed and start-up delay are both reported as predictors of unsafe crossing behaviour in pedestrian simulation studies in the UK as they negatively affect the ability to complete a road crossing safely (Geraghty, Holland, & Rochelle, 2016). In addition, as a result of increased caution due to fear of falling, older pedestrians have been shown to spend more time looking down at the road surface and watching their steps as they cross the road, compared to younger adults (Avineri, Shinar, & Susilo, 2010; Paquette & Vallis, 2010; Zito et al., 2015). This means that less attention is paid to approaching traffic. In addition, simulation studies have shown that once the road crossing has commenced, younger adults make adjustments to their walking speed in response to a time-gap decrease in approaching vehicles, whereas this in not observed in older pedestrians (Dommes et al., 2014; Lobjois & Cavallo, 2009). Gutters, kerbs and surface changes at the point of road crossing can also provide a challenge to older pedestrians, increasing their risk of falling and slowing their crossing speeds (Tournier et al., 2016).

### 3.1.4 Road crossing among pedestrians with disabilities: current research

Since many chronic medical conditions are associated with ageing, the issues experienced by pedestrians with disabilities are likely to be similar to those experienced by older people in general. These include slower walking speeds and difficulty judging the distance and speed of approaching vehicles (Jancey et al., 2013). Limited research exists on pedestrian safety issues for people with disabilities, however the existing studies are summarised below for common disabilities.

***Visual impairment***

Around five percent of the Australian population aged 50+ have a form of visual impairment. The most common causes are cataract, glaucoma, age-related macular degeneration, diabetic retinopathy and uncorrected refractive error. These conditions are often but not always age-related (Foreman et al., 2016). Previous research has shown that the ability of pedestrians to make accurate street-crossing decisions becomes seriously compromised with impaired vision. For example, they have been shown to identify fewer crossable gaps (Chong, Chiang, Allen, Fleegler, & Lee, 2018), experience difficulty determining whether vehicles are giving way (Ashmead, Guth, Wall, Long, & Ponchillia, 2005), require more time to determine when it is safe to cross and have a higher percentage of unsafe gap determinations (Ashmead et al., 2005; Geruschat, Fujiwara, & Wall Emerson, 2011; Guth, Ashmead, Long, Wall, & Ponchillia, 2005). These difficulties have been reported to increase in high traffic volumes (Guth, Long, Emerson, Ponchillia, & Ashmead, 2013).

#### *3.1.4.1 Dementia*

Dementia affects nearly 10% of Australians aged 65 years or older (Australian Institute of Health and Welfare, 2016), with Alzheimer's Disease (AD) accounting for 60% of cases (Gorrie, Brown, & Waite, 2008). In addition, there are many older adults diagnosed with mild cognitive impairment who are functionally affected but do not meet criteria for dementia (Gorrie et al., 2008). Cognitive ability declines with dementia with brain functions such as attentional processes, secondary memory, word knowledge, visuospatial ability, abstract reasoning and problem solving affected (Fang, Lin, Liu, & Ou, 2018; Gorrie et al., 2008). A study of 52 pedestrian fatalities in Sydney found that crash characteristics were similar to that reported for older pedestrians in general. However, those with hallmarks of AD in brain were more likely to be at least partially responsible for the crash, be injured in low complexity situations, and crash in near traffic lanes (Gorrie et al., 2008). Limited evidence from simulated pedestrian studies have also reported that older adults with dementia or AD specifically had slower walking speeds and more unsafe road crossings than control participants (Dommes et al., 2014; Fang et al., 2018).

#### *3.1.4.2 Multiple sclerosis*

Multiple sclerosis is a neurological disease affecting one in 3000 people. It affects the central nervous system impacting on ambulation, balance, cognition, vision, muscle strength and fatigue (Stratton, Pilutti, Crowell, Kaczmarski, & Motl, 2017). In a virtual street crossing task, participants with multiple sclerosis waited longer to enter the street, were less attentive to traffic before entering, took longer to cross the street and were closer to oncoming vehicles when exiting the street compared to controls It is likely these findings are also applicable to older pedestrians and others with neurodegenerative diseases since they experience similar motor, cognitive and visual impairments (Stratton et al., 2017).

#### *3.1.4.3 Parkinson's Disease*

Parkinson's Disease is a progressive neurodegenerative disorder characterised by motor symptoms including bradykinesia, tremor, rigidity and postural instability (Ford et al., 2017). It affects approximately 1% of people aged over 60 years (Department of Health and Human Services, 2018). Cognitive impairment and sleep dysfunction may also be present. In a virtual reality environment, pedestrians with Parkinson's Disease demonstrated slower walking speed, lower vigilance and riskier pedestrian behaviour resulting in less time to contact with approaching vehicles, compared to control pedestrians (Ford et al., 2017). In a second virtual reality environment study, pedestrians with Parkinson's disease also made more errors in decision making when crossing the road and risk increased with severity of the disease. Crossing time was significantly longer and risk increased with faster approaching motor vehicle speeds (Lin, Ou, Wu, & Liu, 2013).

#### *3.1.4.4 Wheelchair and mobility scooter users*

Wheelchair and mobility scooter users are considered pedestrians. Mobility scooters are devices with two or more wheels used by a single person and propelled by an electric motor (motor must not be capable of travelling more than 10 km/h with maximum output of 200 watts) (Department of Infrastructure, 2018). Wheelchair and mobility scooter users require safe ramps and more spacious pedestrian refuges when crossing roads. They are also lower to the ground than other pedestrians which may affect their visibility. Drivers may also inaccurately judge their speed as standard wheelchair users may be moving slower than other pedestrians or electric wheelchair or mobility scooter users may be moving faster (Kraemer & Benton, 2015). This may increase their risk of crashes when crossing roads. For wheelchairs specifically, an American study found that the mortality rate for pedestrians using wheelchairs was 36% higher than the overall population pedestrian mortality rate. Almost half (48%) of fatal crashes occurred at intersections and 39% of intersection crashes occurred at locations without any traffic control devices, 48% involved a crosswalk and driver failure to give way occurred in 21% of cases. In addition, police attributed 15% of the crashes to wheelchair riders not being sufficiently visible (Kraemer & Benton, 2015). Little research exists for mobility scooters, however evidence indicates that crosswalk design may not be adequate for pedestrians in wheelchairs and mobility scooters and their visibility to drivers may also be an issue contributing to crashes (Kraemer & Benton, 2015).

#### *3.1.4.5 Walking aide users*

Pedestrians using walking aides such as walking sticks or frames require additional space at pedestrian refuges. They are also likely to be travelling at a slower speed than other pedestrians and may fatigue more easily. Since balance may also be an issue for pedestrians using walking aides, kerb and ramp design is important for this group (Department of Transport, 2016).

### 3.1.5 Road environment/ temporal factors and pedestrian crash risk

A small number of studies have examined the road-environment and temporal risk factors for crashes involving older pedestrians. While no detailed data was located from WA, O’Hern et al. recently reported on the most common characteristics of older pedestrians crashes in Victoria (O'Hern et al., 2015). These were:

- Pedestrian crossing the road: 71% of older pedestrian crashes occurred while crossing the road. Others occurred in driveways, parking lots and on paths. Few occurred while walking with or against traffic (O'Hern et al., 2015)
- Near-side lane crashes (O'Hern et al., 2015)
- Mid-block locations (48-51%), followed by cross-intersections (25-27%) and T-intersections (21-26%) (O'Hern et al., 2015)
- Speed limits of 50 or 60 km/h (75%) (O'Hern et al., 2015)
- Daylight hours (>95%) (O'Hern et al., 2015)
- Non- peak traffic periods (O'Hern et al., 2015)
- Arterial shopping precincts with complex traffic environments, on-street parking, high traffic volumes, few pedestrian facilities and wide undivided roads (O'Hern et al., 2015)

Other studies have reported increased risk of vulnerable pedestrian crashes or injury with:

- Complex road environments including mixed traffic, high volume or fast-moving traffic. The simultaneous processing of many sources of information in these environments can be difficult (Dumbaugh, 2008; Naumann, Dellinger, Haileyesus, & Ryan, 2010; O'Hern et al., 2015; Oxley & Fildes, 1999)
- Higher vehicle speeds (more severe injury) (Constant & Lagarde, 2010; O'Hern et al., 2015)

#### 3.1.6 Summary: Part 1

In summary, Part 1 of the literature review identified common issues experienced by older pedestrians and those with disabilities, when crossing the road. Difficulties experienced and characteristics were very similar for older people and those with a variety of disabilities. These included:

- A desire to take the shortest route, even if it is not the safest;
- Willingness to wait longer to cross at traffic lights and higher compliance with signals than other pedestrians;
- Slower walking/ travelling speeds across the road;
- Difficulty with gap selection especially in complex environments, in higher traffic volumes and when the approaching vehicle speed is high;
- Risk of near-side and far-side crashes, depending on type of disability;
- Poor visibility of wheelchair and mobility scooter users for motorists.

Common characteristics of pedestrian crashes involving older pedestrians are: pedestrian crossing the road, near side lane crashes, speed limits of 50 or 60 km/h, daylight hours, arterial shopping precincts and complex road environments.

## 3.2 PART 2: PEDESTRIAN CROSSING OPTIONS IN WA: CURRENT SITUATION

Part 2 describes the current pedestrian crossing options used in WA at mid-blocks, signalised intersections, un-signalised intersections, roundabouts and other locations. It also reviews evidence on the safety of each of these existing options for older pedestrians and those with disabilities.

### 3.2.1 Control and guidelines for pedestrian facilities in WA

Main Roads WA is responsible for managing the State road network, including pedestrian facilities on these roads. Local governments are responsible for planning, constructing and maintaining the pedestrian network on local roads including local distributors and access roads. However, Main Roads WA has jurisdiction for all traffic signals, regulatory signs and pavement markings on all roads throughout WA so are involved in the design and approval process of many pedestrian facilities on local roads (Department of Transport, 2016).

The *"Planning and Designing for Pedestrian Guidelines"* outline good practice for the design and construction of pedestrian facilities in WA (Department of Transport, 2016). The guidelines were co-ordinated by the Department of Transport with collaboration from several other stakeholders including Main Roads WA, Disability Services Commission, Royal Automobile Club (RAC) and the WA Local Government Authority.

This document has been based on a range of standards and guidelines relevant for pedestrian infrastructure. Main Roads WA has a large number of policies, guidelines and specifications applicable to pedestrian facilities on State roads as well as traffic signals, regulatory signs and pavement markings on local roads. The Austroads Guides also provide guidance measures for planning and designing streets for pedestrians. There are also a set of Australian Standards governing pedestrian design. It should be noted that Main Roads Policies as well as applicable reference documents produced by other WA State Government departments, take precedence over the Austroads Guides (Department of Transport, 2016).

### 3.2.2 Mid-block crossing options in WA

A range of crossing options are used in WA to improve pedestrian safety at mid-blocks. These offer different levels of protection for the pedestrian with some granting right of way to the vehicle and others to the pedestrian.

#### *3.2.2.1 Raised medians*

Raised medians separate the road into two separate carriageways which enable pedestrians to cross the road as two short one-way roads using the median as a refuge (Figure 3.1). This provides a continuous crossing option for pedestrians along a stretch of road. However, only physically able pedestrians can cross at these locations. Cut-throughs or refuges are suggested at regular intervals (minimum every 100m) for wheelchair access (Department of Transport, 2016).

#### *3.2.2.2 Painted medians*

Painted medians form a continuous, non-physical divide along the road and are often used in conjunction with pedestrian refuge islands (Figure 3.1). While low cost, painted medians provide little protection for pedestrians (Department of Transport, 2016).

#### *3.2.2.3 Pedestrian refuge islands*

Pedestrian refuge islands are isolated concrete islands located in the middle of the road to enable pedestrians to cross one direction of traffic at a time (Figure 3.1). This is relatively low cost and provides a safe pedestrian refuge. They are suitable for roads with wide lanes and where pedestrian crossing movements are concentrated (Department of Transport, 2016).

**Figure 3.1 Examples of raised median, painted median and pedestrian refuge islands**

(Department of Transport 2016)

#### *3.2.2.4 Zebra crossings*

Zebra crossings consist of white bars painted on the carriageway and give right of way to the crossing pedestrian (Figure 3.2). However, they rely on the motorist seeing the pedestrian and slowing down or stopping for them. Zebra crossings are relatively low cost and create less delays for motorists than signalised crossings. However, pedestrians may assume all motorists will stop and give way. Zebra crossings are appropriate on two lane roads (one lane in each direction) with short crossing distances when there is consistent pedestrian usage, low traffic speeds, low traffic volumes, street lighting and good visibility. There is a Main Roads warrant for installation of zebra crossings which specifies the minimum level of pedestrian and traffic demand before a zebra crossing can be considered  (Department of Transport, 2016).

#### *3.2.2.5 Wombat crossings*

A wombat crossing is a zebra crossing which is located on a raised plateau at footpath level (Figure 3.2). This raised surface improves the visibility of the crossing and forces motorists to lower their speeds. However, this is only suitable in low speed areas of 40 km/h or less (Department of Transport, 2016).

**Figure 3.2 Examples of zebra and wombat crossings**

(Department of Transport 2016).

#### *3.2.2.6 Pelican crossings*

Pelican crossings are traffic signals located at mid-block locations which are activated by the pedestrian (Figure 3.3). The signal sequence of the lights incudes a flashing yellow period for the motorists, allowing them to proceed through the crossing if clear but requiring them to give way to pedestrians if they are still on the crossing. These are suitable where pedestrian crossing is concentrated and there are high traffic volumes and provide minimal delay to motorists. They are also suitable for pedestrians with visibility or mobility impairment but slower pedestrians may struggle to cross in time. They are also an expensive crossing treatment and not suitable for speed limits of 70 km/h or higher (Department of Transport, 2016).

#### *3.2.2.7 Puffin crossing*

The puffin crossing is an *"intelligent"* variation of the pelican crossing. Above ground detectors mounted on the traffic light sense the presence of people crossing the road and adjust the crossing times as required (Figure 3.3). Extra time is allocated for slower moving pedestrians such as older pedestrians and those with disabilities. In addition, the pedestrian phase can be reduced if a pedestrian is not detected. Puffin crossings are flexible, efficient and safer than pelican crossings, but also expensive (Department of Transport, 2016).

**Figure 3.3 Examples of a Pelican crossing (left) and the pedestrian detector on a Puffin crossing (right)**

(Department of Transport 2016)

#### *3.2.2.8 Mid-block crossing options: evidence*

In considering these current mid-block crossing options used in WA, raised medians are not a suitable solution for older pedestrians and those with disabilities, unless regular cut throughs (of adequate width for wheelchairs and walking aides) are provided (Department of Transport, 2016). Painted medians do not provide adequate protection for vulnerable pedestrians (Martin, 2006; Zegeer, Stewart, Huang, & Lagerwey, 2001). In addition, both of these options require pedestrians to determine the best location to cross and select a safe gap in traffic, which may be challenging for some older pedestrians and those with disabilities.

On certain roads, pedestrian refuges or zebra/ wombat crossings could be considered for older pedestrians and those with disabilities. Pedestrian refuges simplify the task of crossing and allow pedestrians to cross in two stages, lightening the cognitive load (Dommes et al., 2014; Retting, Ferguson, & McCartt, 2003). However, they do not give the pedestrian the right of way and gap selection is still required. Zebra crossings give the pedestrian right of way and remove the need for gap selection. They are relatively cheap but are only appropriate and safe under very specific circumstances including two lane roads with short crossing distances, low traffic speeds and volumes (Department of Transport, 2016). Evidence is conflicting as to whether crosswalks with no signals (such as zebra crossings) increase or decrease pedestrian safety (Koepsell et al., 2002; Zegeer et al., 2001) and crossings located on multi-lane, high volume roads have been associated with increased pedestrian crashes (Retting et al., 2003; Zegeer et al., 2001). Since the 1970s, Main Roads WA has replaced a large number of zebra crossings which were located on high volume roads with raised medians or pedestrian refuge islands and this removal resulted in a reduced number of pedestrian crashes (Department of Transport, 2016). Zebra crossings provide guidance to older pedestrians about the safest location to cross but rely on drivers seeing and giving way to pedestrians. However, in suitable road environments, these may be a safe option for older pedestrians and those with disabilities.

It is suggested that where a crossing caters for a large number of older pedestrians or those with a disability, pelican or puffin crossings (signalised crossings) are the safest option (Department of Transport, 2016). Controlled pedestrian crossings with traffic signals which stop all vehicle traffic for pedestrians, have been reported to reduce pedestrian crashes (Retting et al., 2003), providing the pedestrian phase is long enough for slower pedestrians to cross the whole road (Romero-Ortuno, Cogan, Cunningham, & Kenny, 2010). Since older pedestrians are more likely to comply with traffic signals than younger pedestrians (Department of Transport, 2016), this option is clearly the safest for vulnerable pedestrians. The disadvantages of pelican and puffin crossings however, are the higher cost and disruption to traffic flow. Puffin crossings are particularly beneficial for vulnerable pedestrians since they sense the presence of people on the road and adjust crossing times as required. They can also reduce the pedestrian phase if it is not needed, to improve traffic flow (Department of Transport, 2016). According to Main Roads WA, all future mid-block signalised pedestrian crossings will be Puffins, however there is no plan to upgrade existing Pelicans to Puffins (Department of Transport, 2016). Due to the obvious safety benefits of Puffin crossings over Pelicans, upgrading Pelican crossings in areas of high use by older pedestrians or those with disabilities to Puffins could have safety benefits.

### 3.2.3 Signalised intersection crossing options in WA: Phasing

In WA, different signalised intersection phasing options offer different levels of protection for pedestrians. At traffic lights, pedestrians have priority over vehicles turning into the street the pedestrian is crossing. Pedestrians must currently use a push button to activate the pedestrian crossing phase (green person signal).

#### *3.2.3.1 Circular signals*

Several existing signalised intersections in WA have circular signals only (with no pedestrian signal) which allow pedestrians to cross whenever the green traffic light is displayed. This is also called a parallel pedestrian crossing with no protection by vehicle signals. This signal provides no indication of when lights are about to change and rely on turning vehicles giving way to pedestrians crossing the road. Push buttons are often provided which extend the normal green time to allow pedestrians time to cross the road. These traffic signals are progressively being upgraded to symbolic pedestrian signals in WA (Department of Transport, 2016).

#### *3.2.3.2 Parallel pedestrian crossing: partial protection by vehicle signals*

These parallel crossings have pedestrian signals and pedestrians are partially protected by getting a head start of 3-5 seconds to cross the intersection before the parallel traffic flow commences. After this time period, vehicles receive a green light (circular or arrow) and can turn, but still have to give way to pedestrians. Disadvantages are delays to traffic and motorists possibly not giving way when turning (Department of Transport, 2016).

#### *3.2.3.3 Parallel pedestrian crossing: full protection by vehicle signals*

Fully protected parallel crossings allow pedestrians to cross on the pedestrian signal at the same time as parallel traffic but they are fully protected as all vehicles are prohibited from turning using red arrows. These signals are usually used when sight distance is poor, speed of traffic exceeds 50 km/h and volumes of turning traffic are high or there is significant use by children, older pedestrians or people with a disability (Department of Transport, 2016).

#### *3.2.3.4 Exclusive pedestrian phase*

Exclusive pedestrian phases allow pedestrians to cross in all directions simultaneously while no traffic is moving. This provides high levels of protection for pedestrians but creates significant delays in traffic movements. It also increases the pedestrian waiting time for a green signal. Currently, intersections with exclusive pedestrian phasing are largely being replaced with parallel phasing in WA (Department of Transport, 2016).

#### *3.2.3.5 Phasing options: evidence*

In considering the pedestrian signal phasing options for signalised intersections, it is clear that circular signals with no pedestrian signals are not a safe option for older pedestrians and those with disabilities. Parallel crossings where pedestrians are partially protected from vehicles by getting a head start of 3-5 seconds to cross the intersection are also likely to be unsuitable for older pedestrians and those with disabilities. Research has shown that these head starts reduce pedestrian crashes by allowing pedestrians to enter the intersection, be visible to drivers and claim priority before turning traffic receives a green signal (Van Houten, Retting, Farmer, & Houten, 2000). However, slower moving pedestrians may not cover much distance during the head start and must still rely on turning drivers seeing and giving way to them. Parallel crossings with full protection by vehicle signals provide a high level of protection for older pedestrians and those with disabilities as they do not have to watch for turning vehicles (Department of Transport, 2016), provided the pedestrian phase is long enough for them to cross the whole road in time.

There has been quite extensive research internationally into the safety of exclusive signal phasing for pedestrians. While most research has reported reduced crashes as a result of exclusive phasing (Bechtel, Macleod, & Ragland, 2004; Gårder, 1989; Yang, Ma, & Lin, 2005), significant increases in pedestrian violations at these signals have also been reported, likely due to pedestrians having to wait longer to cross (Bechtel et al., 2004; Ivan, McKernan, Zhang, Ravishanker, & Mamun, 2017). A study of 93 pedestrian crashes in the Perth CBD between 2008 and 2012 found that approximately half of traffic light crashes had parallel phasing and half had exclusive phasing. Illegal pedestrian crossing behaviour and pedestrians failing to clear intersections (late completers) were proposed as likely scenarios underlying this crash pattern and mitigating the protective effects of exclusive walk intersections (Palamara & Broughton, 2013).

These findings suggest that exclusive pedestrian phasing is only safer for pedestrians when they actually comply and wait for the 'walk' signal. Since older pedestrians have been shown to be willing to wait longer at signals (Guo et al., 2011; Paschalidis et al., 2016) and are less likely to violate these signals (Dommes et al., 2015; Granié et al., 2013; Ren et al., 2011; Rosenbloom et al., 2004), it is likely that exclusive phasing would be a safe option for older pedestrians and those with disabilities. However, since 2001, pedestrian crossings in WA have been progressively updated to parallel phasing as this configuration was preferred over exclusive phasing by motorists, cyclists and pedestrians due to minimal delays to crossing (Department of Transport, 2016). Since it would be undesirable to improve the safety of older pedestrians and those with disabilities at the expense of other pedestrians, parallel crossings with full protection instead provide a good, safe option. However, in order to make parallel crossings safe for slower moving pedestrians, longer pedestrian phases or the introduction of technology that can detect pedestrians still in the intersection (like at Puffin crossings) may be required.

### 3.2.4 Signalised intersection crossing options in WA: audio-tactile facilities

Audio-tactile pedestrian signals provide audible and tactile cues that duplicate visual cues at signalised intersections. An audio-tactile push button is mounted on the traffic signal pole with tactile arrows indicating the direction of the crossing phase (Figure 3.4). The unit emits different audible tones and tactile pulses. They are used by pedestrians with visual and other disabilities to identify whether the pedestrian crossing lights are green, orange or red (Department of Transport, 2016).

#### *3.2.4.1 Audio-tactile facilities: evidence*

In WA, audio-tactile facility placement and design is governed by Main Roads WA Guidelines and it is required that these be installed wherever visual pedestrian signals are provided, including signalised traffic intersections and signalised dedicated pedestrian crossings (Department of Transport, 2016).

**Figure 3.4 Example of an audio-tactile facility at traffic lights**

(Department of Transport 2016)

### 3.2.5 Signalised intersection crossing options in WA: countdown timers

Pedestrian countdown timers replace the flashing red person and inform pedestrians how many seconds they have left to cross the road, meaning pedestrians are less likely to start crossing when there is not enough time to reach the other side of the road safely. These are currently installed at approximately 40 traffic light intersections in WA, with the majority in the metropolitan area (Figure 3.5). Countdown timers now form part of the approved Main Roads WA standards and will continue to be installed at further sites (Main Roads Western Australia, 2018).

#### *3.2.5.1 Countdown timers: evidence*

Countdown timers have been reported to be popular and received positively by pedestrians and motorists (Lambrianidou, Basbas, & Politis, 2013; Main Roads Western Australia, 2018). However, several studies have investigated the effectiveness of countdown timers and reported mixed results. Some studies reported that the introduction of the timers had no effect on pedestrian signal compliance (Huang & Zegeer, 2000; Markowitz, Sciortino, Fleck, & Bond, 2006) or increased red light offending by pedestrians due to running across the road at the last minute or overestimating their ability to cross in the remaining time (Zhuang & Wu, 2018). Others have reported increased pedestrian compliance after installation of countdown timers (Eccles, Tao, & Mangum, 2003; PHA Consultants, 2005). Interestingly, one study found that the timers decreased compliance in those aged under 40 years but had a particularly positive effect on compliance in those aged 60+ as well as for slow-moving pedestrians (Lipovac, Vujanic, Maric, & Nesic, 2013). A Canadian study reported a decrease in pedestrian crashes overall after installation of countdown timers but an increase in older pedestrian crashes (Rothman, Cloutier, Macpherson, Richmond, & Howard, 2017). The authors suggested that this was due to older pedestrians having difficulty completing a crossing in time, irrespective of the presence of countdown timers. This highlights the importance of ensuring the crossing time allocated to pedestrians at the intersection is adequate to allow older and slower pedestrians to cross in time, in order for countdown timers to have positive safety effects.

Overall, countdown timers would appear to have a positive effect on safety for older pedestrians and those with a disability. This is due to increased signal compliance by assisting them in making a decision about whether it is safe to begin a road crossing. Main Roads WA plan to continue installing the timers at WA intersections and targeting areas with larger numbers of older pedestrians or those with disabilities could improve pedestrian safety outcomes.

**Figure 3.5 Example of a countdown timer at traffic lights**


(Main Roads Western Australia, 2018)

### 3.2.6 Signalised intersection crossing options in WA: Pedestrian signal timing

The timings for pedestrian signals in WA usually consist of a walk period (green figure) which is a minimum of six seconds and a clearance period (red flashing figure) timed based on a walking speed of 1.2 metres per second. However, at sites with higher proportions of slower moving pedestrians, a walking speed of 1.0 m/s can be used. Cycle times at co-ordinated intersections are often long involving pedestrians waiting over two minutes to cross the road. This waiting time often results in failure to observe the pedestrian signals. In busy pedestrian areas, phases to prioritise pedestrian movements can be introduced (Department of Transport, 2016).

#### *3.2.6.1 Pedestrian signal timing: evidence*

Walking speeds impact on the ease and safety of pedestrians crossing at traffic lights, with slower pedestrians needing a longer time to cross. (Department of Transport, 2016). Several studies have reported that most older adults walk at a slower pace than 1.2 m/s. For example, a Brazilian study reported that 97.8% of people aged 60+ walked slower than 1.2 m/s (Duim, Lebrão, & Antunes, 2017). A Swiss study reported that 36% of those aged 70-79 years and 74% of those aged 80+ walked slower than 1.2 m/s when also performing a cognitive task (Eggenberger, Tomovic, Munzer, & de Bruin, 2017). An Irish study used linear regression analysis to predict the average walking speeds of older adults of different ages and predicted speeds of 1.3 m/s at 60 years, 1.1 m/s at 70 years, 0.9 m/s at 80 years and 0.7 m/s at 89 years (Romero-Ortuno et al., 2010). These figures indicate that a crossing time based on 1.2 m/s would be inadequate for most older adults and 1.0 m/s would be insufficient for pedestrians aged 80+, as well as those with certain disabilities. Inadequate crossing time puts older pedestrians and those with disabilities at risk of falls (due to rushing) and far side crashes at traffic lights.

These findings indicate that older pedestrians and those with disabilities require longer, fully protected pedestrian phases at traffic lights in order to cross safely. Some cities in Spain for example, have reduced the reference walking speed of pedestrian crossings to 0.9 m/s in order to cater for the ageing population (Romero Ortuño, 2016). However, extended pedestrian phases impact on traffic flow. Intelligent crossings that are able to detect pedestrian movements and only extend the pedestrian phase if they remain on the crossing would be useful. This technology is currently used at Puffin crossings in WA, but not standard traffic light intersections.

### 3.2.7 Non-signalised intersection crossing options in WA

Non-signalised intersections include those controlled with give-way or stop signs. Pedestrians at non-signalised intersections have priority over turning vehicles. However, this is not always observed. One treatment that may improve pedestrian safety is keeping kerb radii to a minimum to reduce the speed of turning vehicles and encourage the pedestrian to cross close to the corner. This has to be balanced with allowing for rubbish trucks and preventing rear end crashes between motor vehicles. Secondly, there are benefits to locating pedestrian crossing ramps at non-signalised intersections, back slightly from the intersection. This increases pedestrian visibility and makes crossing distances shorter. However, the deviation of pedestrians from their path should be minimal or use of the crossing will be discouraged. (Department of Transport, 2016).

#### *3.2.7.1 Non-signalised intersection crossing options in WA: evidence*

Pedestrian crossing options at non-signalised intersections are quite limited. The above options which reduce vehicle speeds and improve visibility at these locations should be implemented to improve safety for older pedestrians and those with disabilities.

### 3.2.8 Roundabout crossing options in WA

At roundabouts, turning vehicles are not required to give way to pedestrians. Splitter islands are commonly used to enable pedestrians to cross one direction of traffic at a time. In addition, zebra crossings are used where pedestrian volumes are high, speeds are 40 km/h or less, there is a high proportion of people with a disability or there are excessive delays for pedestrians.

Traffic signals are occasionally used when pedestrian and traffic volumes are high, particularly if the pedestrians are older or have a disability (Department of Transport, 2016).

#### *3.2.8.1 Roundabout crossing options in WA: evidence*

Roundabout pedestrian crossing options are also quite limited. However, as stated above, in areas where there are higher numbers of older pedestrians and those with disabilities, higher level treatments such as zebra crossings or traffic signals should be considered (Department of Transport, 2016).

### 3.2.9 Grade separation

Grade separation of a pedestrian crossing from a roadway can be achieved using a bridge or an underpass. This type of crossing eliminates conflict between pedestrians and vehicles and does not result in any disruption to traffic (Department of Transport, 2016).

#### *3.2.9.1 Grade separation: evidence*

The high cost and additional crossing length due to the level difference mean these crossings are only practical for use in WA on freeways and high-speed highways carrying large traffic volumes. The level difference can also cause problems for older people and pedestrians with disabilities. This treatment is suitable in specific situations but not for widespread use (Department of Transport, 2016).

### 3.2.10 Speed limits, traffic calming and traffic volume

Reduced speed limits, variable speed limits, traffic calming and strategies to reduce motorised traffic volumes are treatments which can be applied along whole lengths of heavy pedestrian areas. These are particularly suited to complex environments with mixed traffic such as shopping, business or entertainment areas (Oxley & Fildes, 1999). Lower speed limits, especially in these areas are known to reduce crash risk and severity for all pedestrians. In addition, variable speed limits controlled by electronic signs are sometimes used on roads which experience high pedestrian volumes during the day and predominantly vehicle traffic at night (Figure 3.6). These speed reductions improve pedestrian safety by reinforcing an appropriate traffic speed (e.g. 40 km/h) through busy activity centres (Department of Transport, 2016). Vehicle speed reductions can also be achieved using traffic calming devices such as speed humps and chicanes, where appropriate and complement reduced speed limits. Finally, if feasible pedestrian exposure to traffic can by decreased by reducing traffic volumes in high pedestrian areas through encouraging alternative routes for motorised vehicles (Oxley & Fildes, 1999).

#### *3.2.10.1 Speed limits, traffic calming and traffic volume: evidence*

Research has shown that reduction in vehicle speeds in general is one of the most effective safety interventions for reducing pedestrian deaths and injuries and even small differences in vehicles speeds can have large effects. For example, among all pedestrians, if struck by a vehicle at 45 km/h, less than 50 percent of pedestrians survive; however, at 30 km/h, more than 90 percent survive (Constant & Lagarde, 2010). The implementation of 30 km/h speed limits in high pedestrian areas of London have also been associated with a 42% reduction in road injury (Grundy et al., 2009; Steinbach, Grundy, Edwards, Wilkinson, & Green, 2010). Therefore, lower speed limits or variable speed limits in areas of older pedestrians and pedestrians with disabilities would be highly effective in reducing crashes and the severity of crashes. This can be complemented with traffic calming devices such as speed humps and chicanes which reduce vehicle speeds, where appropriate. In addition, lower vehicle speeds would improve safe gap selection by older pedestrians and those with disabilities who may have difficulty judging the distance of faster vehicles (Dommes & Cavallo, 2011; Dommes et al., 2014; Oxley et al., 2005). Finally, reduced traffic volumes in high pedestrian areas would reduce exposure to traffic as well as the complexity of the environment, improving safety for vulnerable pedestrians (Oxley & Fildes, 1999).

**Figure 3.6 Example of a variable speed limit sign**


(Department of Transport 2016)

### 3.2.11 Shared zones

Shared zone are zones where pedestrians and vehicles share the same space. There are very few of these in WA. Vehicles are required to give way to pedestrians and very low speed limits (e.g. 10 km/h) are applied (Department of Transport, 2016).

#### *3.2.11.1 Shared zones: evidence*

Shared zones are appropriate in busy commercial, tourist and heritage areas and should have low traffic volumes, a different surface texture from the surrounding road network and use traffic calming measures (Department of Transport, 2016). While the very low speed limits in shared zones would benefit older pedestrians and those with disabilities, this treatment is only suitable for very specific areas and not for widespread implementation.

### 3.2.12 Tactile ground surface indicators

Tactile ground surface indicators (TGSI) are implemented at signalised and non-signalised intersections in WA as well as other locations. TGSI provide physical or tactile cues for people who are blind or have low vision. They are applied to the ground in the path of travel and their design is governed by Australian Standards. Warning TGSI consist of a series of raised dots to warn of a hazard such as a road (Figure 3.7). In WA, warning TGSI are required on kerb ramps onto busy or hazardous streets and on pedestrian cut-throughs. They are also applied where flush kerbs meet the road. Directional TGSI consists of a series of raised bars to indicate the direction of the safe path of travel. They are used for example, to identify the point at which a pedestrian needs to turn to access a mid-block pedestrian crossing. (Department of Transport, 2016).

#### *3.2.12.1 Tactile ground surface indicators: evidence*

TGSI are known to be highly useful and essential for visually impaired pedestrians and are a requirement in many situations in WA. However, several crossing locations which should have TGSI currently do not in WA so full implementation of these would improve pedestrian safety. It should also be noted however that TGSI can cause issues for other pedestrians including those with wheelchairs and other walking aides, so careful application is necessary (Department of Transport, 2016).

**Figure 3.7 Warning tactile ground surface indicators**

(Department of Transport 2016)

### 3.2.13 Summary: Part 2

Main Roads WA manages the State road network and also has jurisdiction for all traffic signals, regulatory signs and road markings on all roads in WA, including local roads.

At mid-blocks, Puffin crossings, followed by Pelican crossings (signalised) provide the safest options for older pedestrians and those with disabilities. On certain roads, pedestrian refuges or zebra/ wombat crossings may also provide safe options. Raised medians and painted medians are not suitable solutions for these vulnerable pedestrians.

At signalised intersections, parallel crossings with full protection by vehicle signals provide a high level of protection for vulnerable pedestrians as they do not have to watch for turning vehicles (provided the pedestrian phase is long enough for them to cross the whole road in time). It is likely that exclusive phasing would also be a safe option for older pedestrians and those with disabilities, but this type of phasing is not favourable for other pedestrians and motorists.

Pedestrian signal timing in WA is generally based on a walking speed of 1.2 m/s but 1.0 m/s can be used for slower moving pedestrians. Evidence indicates that a crossing time based on 1.2 m/s would be inadequate for many older adults to cross the whole road and 1.0 m/s would be insufficient for pedestrians aged 80+. Extending pedestrian phases or use of technology that detects pedestrians who remain in the intersection and extend the crossing time, could increase safety for older pedestrians and those with disabilities.

Pedestrian countdown timers at signalised intersections may have a positive effect on safety for older pedestrians and those with a disability. This is due to increased signal compliance by assisting them in making a decision about whether it is safe to begin a road crossing. Main Roads WA plan to continue installing the timers at WA intersections. Targeting areas with larger numbers of older pedestrians or those with disabilities could improve pedestrian safety outcomes.

In areas of high pedestrian activity, particularly complex environments with a high volume of mixed road users, reduced speed limits, variable speed limits, traffic calming and reduced traffic volumes could also be highly effective in reducing crashes and crash severity among older pedestrians and those with disabilities.

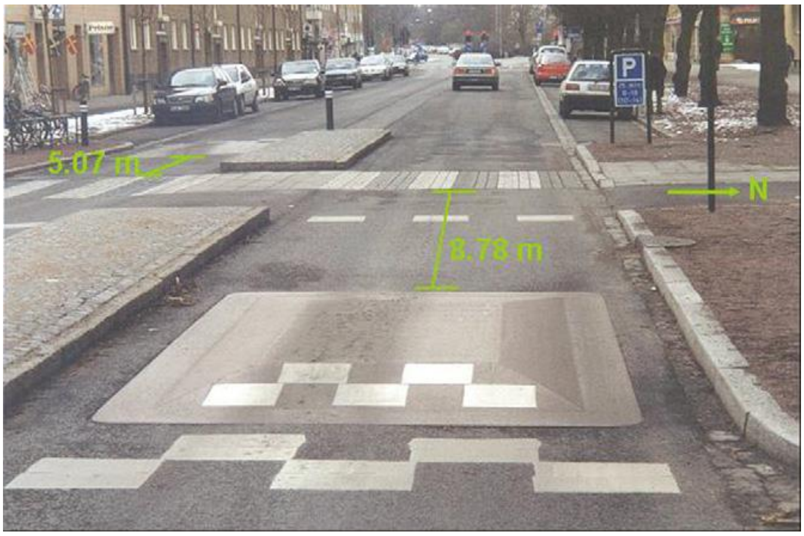
## 3.3 PART 3: ALTERNATIVE CROSSING OPTIONS FOR PEDESTRIANS

Part 3 describes several pedestrian crossing options that are used in other countries as well as new, emerging options. Where available, evidence of their effectiveness is provided.

### 3.3.1 Speed humps on approach to zebra crossings

Speed humps or cushions on approach to zebra pedestrian crossing are a common physical measure used in Europe to increase safety for pedestrians at mid-blocks (Figure 3.8). Previous research has suggested that under standard conditions, drivers do not adapt their speed in such a way that they do not endanger pedestrians who are already on or about to enter the zebra crossing (Várhelyi, 1998). In WA, zebra crossings are usually painted on the road or located on a raised platform to form a Wombat crossing (Department of Transport, 2016). However, to our knowledge speed humps on approach to zebra crossing are not used on WA roads, only occasionally in shopping centre carparks.

**Figure 3.8 Speed hump/ cushion on approach to a zebra crossing in Sweden**




(Johansson, Rosander, & Leden, 2011)

#### *3.3.1.1 Evidence of effectiveness*

Several studies have investigated the effects of these speed humps/ cushions on approach to zebra crossings on road user behaviour. For example, a recent before and after study in Israel examined the impact of installing raised pedestrian crossings with a speed hump on approach on driver behaviour (Gitelman, Carmel, Pesahov, & Chen, 2017). Each crosswalk itself was on a trapezoidal speed hump and a preceding circular speed hump in each travel direction was installed as well as traffic signs. Before the installation, vehicle approach speeds to the crossing averaged 42-58 km/h. After the installation, for sites with a lower hump (6-8cm) installed, average speeds reduced to 31-37 km/h and for sites with a higher hump (8-10cm) installed, speeds averaged below 30 km/h. At some sites there were also improved rates of giving way to pedestrians by drivers, reduced vehicle-pedestrian conflicts and an increase in the percentage of pedestrians who crossed in the designated area (Gitelman et al., 2017).

Another study in Sweden examined the impact of different distances between speed cushions and zebra crossings at three sites (Johansson et al., 2011). Speed cushions were placed at distances of 5m or 10m before the crossing. Results found vehicles speeds were low for both distances with an overall average of 22-23 km/h but that vehicle speeds were lower at the pedestrian crossings where the distance between the speed hump and the crossing were greater. Longer distances also made it easier for pedestrians to distinguish whether a driver was going to stop or not (Johansson et al., 2011).

Evidence suggests that speed humps on approach to zebra crossings lower vehicle speeds and possibly increase vehicle compliance with pedestrian right of way. Therefore, this option may make zebra crossings safer for older pedestrians and those with disabilities in WA. It should be noted however, that speed humps are only appropriate under certain circumstances such as on straight roads with lower traffic volumes. Speed humps can increase traffic noise in residential areas and can cause problems for buses, commercial vehicles and emergency services, so this treatment must be used with caution (Department of Transport, 2016; Várhelyi, 1998).

### 3.3.2 Rectangular Rapid Flashing Beacons

Rectangular Rapid Flashing Beacons (RRFB) are amber LEDs mounted on pedestrian signs that supplement warning signs at un-signalised intersections or mid-block crosswalks (Figure 3.9). They have been widely used in North America on single or multi-lane roads which pedestrians are required to cross, for example, outside hospitals. The lights flash in an irregular pattern and the novelty and unique nature of the stutter flash is intended to elicit at greater response from drivers than traditional methods. The lights may either be activated via a push button or by an automatic pedestrian detection system. The crossings also include pedestrian crossing signs, stop lines and in-pavement flashers. RRFBs present a lower cost alternative to installing pedestrian traffic lights and give pedestrians priority at all times (Federal Highway Administration, 2009).

**Figure 3.9 Rectangular Rapid Flashing Beacons in the USA and Canada**


(Moshahedi, Kattan, & Tay, 2018; Sohrweide, 2018)

#### *3.3.2.1 Evidence of effectiveness*

The effectiveness of RRFBs in North America have been quite extensively evaluated and positive findings have been reported. An analysis of the RRFB pictured first in Figure 3.9, located outside a hospital in Minnesota observed the crossing on two separate days. It was reported that 82% of pedestrians pushed the RRFB button to activate the lights and 96% of vehicles stopped for pedestrians (Sohrweide, 2018). Only two percent of pedestrians crossed the road at a location other than the RRFB (Sohrweide, 2018). Evaluations of RRFBs by the

FHWA in the USA found firstly that going from a no-beacon arrangement to a two-beacon system mounted on the supplementary warning sign increased vehicle yielding from 18% to 81% and a four-beacon system increased yielding to 88% (Shurbutt & Van Houten, 2010). The yielding distances given by motor vehicles also increased. Secondly, traditional pedestrian over-head yellow beacons produced a minimal increase in yielding while the rapid flashing beacon produced a marked increase. Thirdly, there was little to no decrease in yielding behaviour after installation of the RRFBs over a one-year period (Shurbutt & Van Houten, 2010).

A more recent analysis in the USA found that drivers were 3.7 times more likely to yield to pedestrians when a beacon was activated, than when it was not activated (Potts et al., 2015). Another study also reported vehicle speed reductions when beacons were activated (Dougald, 2016). A recent evaluation in Canada examined factors associated with motorist compliance at 19 RRFBs and reported that compliance was higher on smaller roads, on roads with lower speed limits and on roads with a median or refuge island for pedestrians. The colour and flashing patterns of the beacons had no significant effect on yielding compliance (Moshahedi et al., 2018).

Use of RRFBs in North America appears to be predominantly as a low-cost alternative to fully signalised pedestrian crossings such as the Pelican or Puffin crossings used in WA. Main Roads WA has very strict criteria for roads which are suitable and safe for zebra crossings including no more than one lane of traffic in each direction and a maximum posted speed limit of 50 km/h (Department of Transport, 2016). It is likely that several of the roads that RRFBs have been implemented on in North America would not be considered suitable for zebra crossings in WA but Pelican or Puffin crossings would be used instead. Since Pelican and Puffin crossings offer the highest level of protection for pedestrians, it is not recommended that RRFBs be considered as an alternative to these. However, since positive safety benefits have been reported after installation of RRFBs, it is possible that the addition of features such as flashing beacons, extra signage and vehicle stop lines may enhance safety for older pedestrians and those with disabilities at existing zebra crossings in WA.

### 3.3.3 Starling Crossing

The Starling Crossing (STigmergic Adaptive Responsive LearnING Crossing) is a *"smart"* pedestrian crossing developed by Umbrellium in the UK (Umbrellium Ltd, 2018). This technology involves a *"responsive surface"* which is laid over a normal road surface and contains a layer of ultra-bright LEDs which are protected by a layer of high impact plastic (Figure 3.10). The road surface component interacts with two cameras which monitor the crossing from each side of the road. The system analyses the road environment and decides what form of crossing is needed. When a pedestrian approaches the crossing area (indicated by a red circle on the pavement), the Starling Crossing appears on the road in the form of the familiar zebra crossing. White lines indicate where motor vehicles should stop ahead of the crossing. Red and green lights on the road for motor vehicles and pedestrians indicate when it is safe to proceed. Once all pedestrians have crossed the road, the crossing disappears until required again. The crossing is able to respond in less than one hundredth of a second. In an emergency situation where someone steps onto the road when unsafe, the crossing lights up with red chevrons warning oncoming traffic to stop and also directing the pedestrian back to the pavement. In times of heavy pedestrian traffic the markings of the crossing become wider and the vehicle stop line is moved back (Umbrellium Ltd, 2018).

#### *3.3.3.1 Evidence of effectiveness*

This technology has not been applied in the real world to date so there is no evidence available on its effectiveness for safety. However, in the future, the Starling crossing could be very useful for older pedestrians and those with disabilities since the technology is responsive to the pedestrian, warns them if they make an error and allows them as much time as required to cross the road.

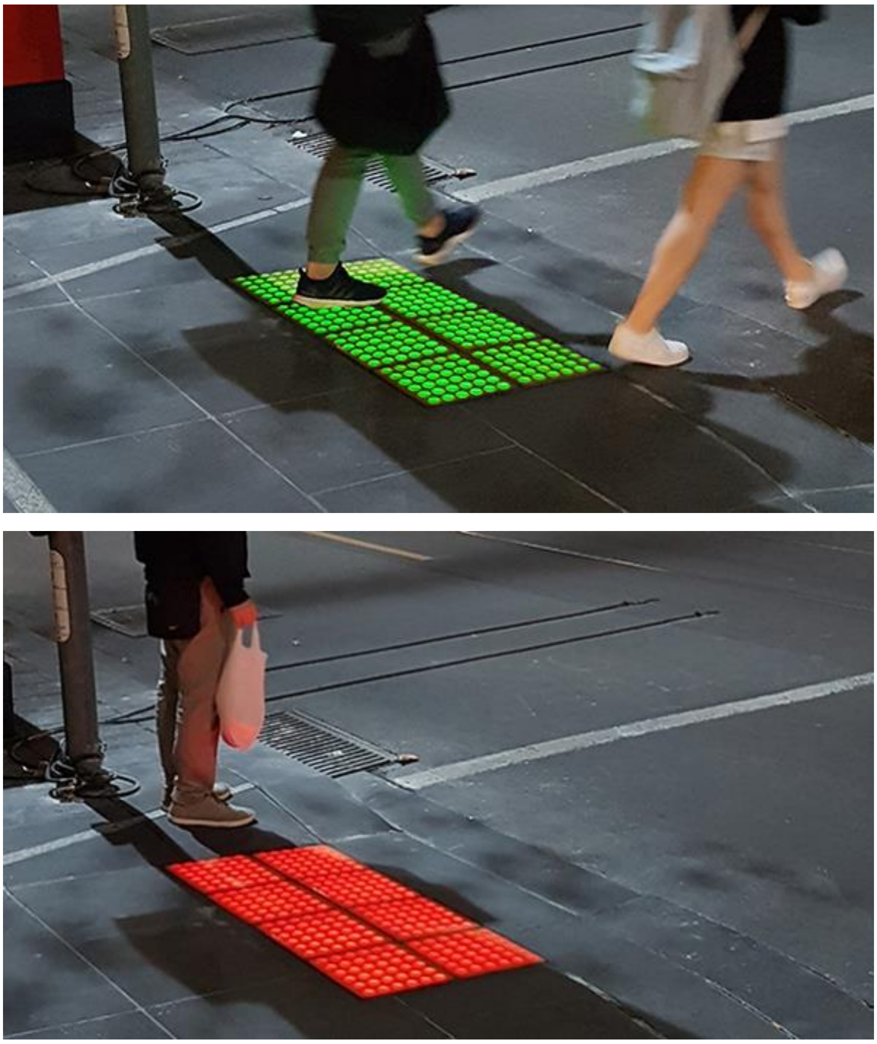
**Figure 3.10 The Starling Crossing in the UK**


(Umbrellium Ltd, 2018)

### 3.3.4 In-ground pedestrian traffic lights

In-ground pedestrian traffic lights are a recent technology consisting of LED lights installed in rows on the kerbside of a signalised pedestrian crossing at an intersection (Figure 3.11). They are connected to the traffic lights and shine the same colour as the pedestrian crossing signals. They are used in Korea, Germany and the Netherlands and have recently been introduced at selected intersections in Sydney and Melbourne. The intention of these lights is to alert pedestrians who are distracted and looking down (usually due to mobile phones) that they are approaching a road and to stop (Vivacity, 2018).

**Figure 3.11 In-ground pedestrian lights in Melbourne**



(Vivacity, 2018)

#### *3.3.4.1 Evidence of effectiveness*

An evaluation of the in-ground lights at 20 intersections in Seoul, Korea reported a 26% reduction in the number of pedestrian crashes, a 21% reduction in injuries and a 38% reduction in pedestrian deaths following installation (Vivacity, 2018). A trial in Sydney however, did not show such positive results. It was found that the installation reduced the proportion of people crossing on a red light to less than 12% but that this did not involve a higher rate of people looking at phones, compared to those who were paying attention, It was suggested that the small decrease in violations did not justify the cost of the treatment in the Sydney context and that pavement markings or additional signage may be more cost effective (Friswell, Williamson, Hatfield, & Senserrick, 2017). It is likely that the higher volume of pedestrian traffic and number of pedestrian crashes in Korea contributed to the higher effectiveness of the treatment.

Since older pedestrians and those with disabilities have been shown to be more compliant with traffic signals than other pedestrians (Lipovac et al., 2013) and they are less likely to be distracted by mobile phones, it is unlikely that in-ground pedestrian traffic lights would have a great benefit for the safety of these pedestrians.

### 3.3.5 SafeWalk and C-Walk

SafeWalk is a pedestrian detection system originally developed by Traficon manufacturers in Belgium (Figure 3.12) (Kirkham, 2011). SafeWalk detects pedestrians using a number of video cameras and an algorithm-based identification system. It dynamically controls traffic lights to optimise pedestrian and vehicle traffic. Pedestrian push buttons are not required. When waiting, approaching or kerbside pedestrians are detected, it activates green time for pedestrians and when no pedestrians are present, it maintains a steady flow of vehicle traffic and keeps the pedestrian crossing on red. This technology can also be used for pedestrian crossings without traffic lights but which have flashing beacons or in-road lighting (Kirkham, 2011). However, with SafeWalk, the pedestrian crossing phase timing is set meaning phases cannot be adjusted for faster or slower pedestrians. C-Walk, also developed by Traficon is an extension of SafeWalk and also uses video camera technology to detect moving pedestrians actually crossing the crosswalk. After detection, the system can extend the pedestrian crossing phase for slower pedestrians or reduce it if the pedestrian clears the crosswalk quickly (Kirkham, 2011).

#### *3.3.5.1 Evidence of effectiveness*

Automatic pedestrian detection technology has been used, predominantly in the US since the 1990s. Microwave radar and infrared technology was most commonly used and an early evaluation in the US reported that use of this technology resulted in more pedestrians being able to complete a crossing in time and a significant reduction in vehicle/ pedestrian conflicts

(Hughes, Huang, Zeeger, & Cynecki, 2001). However, problems with high numbers of false detections due to shadows, trees and vehicles with microwave and infrared systems led to the development of video technology detection systems like the SafeWalk and C-Walk (Kirkham, 2011). A study was conducted to evaluate the effectiveness of the SafeWalk and C-Walk at detecting pedestrians, however they did not evaluate the impact on road safety. SafeWalk was able to rapidly detect and track pedestrians entering and leaving the wait area and stationary pedestrians within it, even at low light levels. The C-Walk was able to quickly detect pedestrians stepping onto the crossing as well as detecting when crossing was completed, even at low light levels (Kirkham, 2011).

The passive pedestrian detection provided by SafeWalk and C-Walk has advantages for pedestrians with physical disabilities and those with low vision as they are not required to make physical contact with the pedestrian button. In addition, the C-Walk would be of benefit to older and slower moving pedestrians as it would give them as long as required to cross the intersection. This technology is similar to that which is currently used at Puffin crossings in WA. The use of pedestrian detection technology at signalised intersections would likely provide safety benefits for older pedestrians and those with disabilities.

**Figure 3.12 SafeWalk and C-Walk pedestrian detection system**

(Kirkham, 2011)

### 3.3.6 Pedestrian switch pads

Pedestrian switch pads are an alternative to using cameras for pedestrian detection at signalised intersections and are developed by Australian-based Traffic Tech (Traffic Tech Pty Ltd, 2010). Pedestrian switch pads are pressure-sensitive tactile pads which are 3.5 mm tall with a 1.5 mm lip and adhere to existing pedestrian ramps at intersections (Figure 3.13). They offer passive presence detection for pedestrians, wheelchairs and bicycles as they approach or wait at a crossing. The pad is a supplement to the push button and can also cancel a crossing request if the pad is vacated, keeping motor vehicle traffic moving. The pads can also detect the direction of movement of the pedestrian stepping on the switch pad. The software is compatible with all existing traffic control systems (Traffic Tech Pty Ltd, 2010).

**Figure 3.13 Pedestrian switch pads**

(Traffic Tech Pty Ltd, 2010)

#### *3.3.6.1 Evidence of effectiveness*

There is no information available on the effectiveness of this intervention for pedestrian safety. A weakness of this technology is that it depends on pedestrians actually stepping on the switch pad or else they will not be detected. Therefore, optimal placement is essential so that pedestrians step on them and trigger the signal. Pedestrian switch pads are a cheaper option than the SafeWalk/ C-Walk described above. However, the pads are not able to detect pedestrians who remain on the crossing and extend the pedestrian phase accordingly, meaning the SafeWalk/ C-Walk would be more beneficial for the safety of older pedestrians and those with disabilities.

### 3.3.7 The *"Green Man"* Scheme

The *"Green Man"* scheme is an innovative system in Singapore that extends the crossing time for older pedestrians and those with disabilities at selected crossings, when they activate the Green Man function (Land Transport Authority, 2013). This system uses the existing senior citizen or disability concession card that is also used for public transport travel. When the card is tapped on a reader mounted above the standard push button on the traffic light pole, the system will extend the green man time by a set amount, which varies depending on the size of the crossing (Figure 3.14). On average, most of the pedestrian crossings have six seconds more green man time when a card is swiped (Land Transport Authority, 2013). At the end of 2018, there will be 1000 pedestrian crossings which have the Green Man function in Singapore.

**Figure 3.14 The *"Green Man"* Scheme reader**


(Land Transport Authority, 2013)

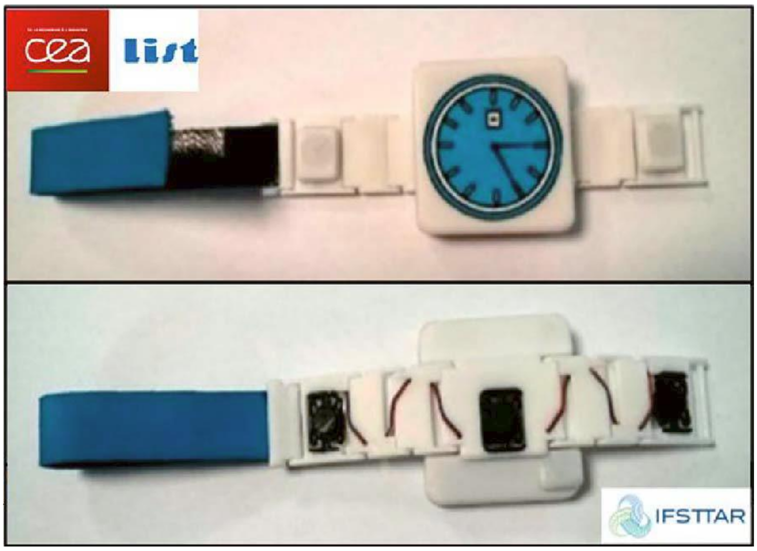
#### *3.3.7.1 Evidence of effectiveness*

The *"Green Man"* scheme has not been evaluated in terms of safety for pedestrians. However, anecdotal evidence suggests that older pedestrians responded well to the scheme, stating they felt more confident when using pedestrian crossings (Land Transport Authority, 2013). It would be possible to introduce such a system in WA using the current SmartRider cards, either on selected or all traffic lights in WA (approximately 1000 sets) and it is likely that this would be beneficial for older pedestrians and those with disabilities. However, information on the cost of this scheme was not available but the benefits and costs would need to be weighed up against the benefits and costs of automated pedestrian detection at traffic lights for older pedestrians and those with disabilities.

### 3.3.8 Vibrotactile wristband

In addition to on-road interventions, advances are also being made in on-person technology for pedestrian safety. A vibrotactile wristband Figure 3.15 was developed in France with the aim of helping older pedestrians make safer street crossing decisions (Coeugnet et al., 2017). This device detects the road environment, approaching vehicle speeds and pedestrian walking speed and sends a vibrotactile message (vibrations) to the pedestrian if there was is enough time for them to cross the entire street safely (Coeugnet et al., 2017).

**Figure 3.15 Vibrotactile wristband**




(Coeugnet et al., 2017)

#### *3.3.8.1 Evidence of effectiveness*

The vibrotactile wristband has been tested in a simulated traffic environment only (Coeugnet et al., 2017). Twenty participants aged 60-69 years, twenty aged 70-80 years and seventeen aged 20-45 years carried out a street crossing task in the pedestrian simulator with and without the wristband. They had to judge whether the gaps in traffic were suitable for street crossing. When wearing the device, a vibrotactile message was sent if the proposed situation did not allow the participant to cross the street safely. Results found the percentage of decisions that led to collisions with approaching cars decreased significantly when participants wore the wristband, with greater benefits observed among very old women. However, participants responded to the vibrotactile message only about half the time since they either disagreed with the signal, ignored it or failed to detect it (Coeugnet et al., 2017). This demonstrates a significant limitation of the device but this could possibly be improved with education and training. Since this device has not been tested in the real-world and is not yet available commercially, it does not present an immediate countermeasure. With further development and testing, such a device could be useful for older pedestrians and those with disabilities in the future.

### 3.3.9 ZebraRecognizer

ZebraRecognizer is mobile phone software for visually impaired people which uses pattern matching techniques to recognise zebra crossings (Mascetti, Ahmetovic, Gerino, & Bernareggi, 2016). It is part of a larger phone app called ZebraX. It uses existing hardware found in all smartphones (camera, accelerometer and gyroscope) to compute a safe path to the zebra crossing and guides the person using audio feedback. It does not however, inform them when it is safe to cross (Mascetti et al., 2016).

#### *3.3.9.1 Evidence of effectiveness*

There has been no evaluation of the effectiveness of the ZebraRecognizer app for the safety of people with visual impairment and it is also not currently commercially available.

### 3.3.10 Summary: Part 3

Part 3 reviewed pedestrian crossing options used in other countries as well as new emerging options.

Options that are currently available and may be useful for older pedestrians and those with disabilities in WA include:

- Speed humps on approach to zebra crossings at mid-blocks
- Use of additional lights, signage and vehicle stop lines at mid-block zebra crossings (as used at RRFB crossings in North America)
- SafeWalk and C-Walk pedestrian detection systems at signalised intersections
- A *"Green Man"* type scheme at signalised intersections

Several of the options reviewed are not currently commercially available but could be useful for older pedestrians and those with disabilities in the future including:

- Starling Crossings at mid-blocks
- On-person crossing technology such as vibrotactile wristbands and ZebraRecognizer mobile phone app

Options that are unlikely to be highly effective for vulnerable pedestrians include:

- In-ground pedestrian lights at signalised intersections
- Pedestrian switch pads at signalised intersections

# 4 CONCLUSION AND RECOMMENDATIONS

This literature review provided an in-depth examination of options to improve the safety of crossing roads by pedestrians in WA, focusing on older pedestrians and those with disabilities.

Part 1 reviewed the literature on common safety issues for older pedestrians and those with disabilities. A large number of studies have examined functional changes in older adults and how these changes affect their ability to cross roads safely. A much smaller number of studies were located examining safety issues for pedestrians with specific disabilities. Overall, common issues and characteristics identified for these groups were: a desire to take the shortest route; higher compliance with traffic signals than other pedestrians; slower walking/ travelling speeds; difficulty with gap selection especially in complex, high traffic volume, high speed environments; risk of near-side and far-side crashes depending on type of disability; and poor visibility of wheelchair and mobility scooter users for motorists (Kraemer & Benton, 2015; O'Hern et al., 2015; Tournier et al., 2016). Research also suggests that crashes involving older vulnerable pedestrians commonly involve: the pedestrian crossing the road, speed limits of 50 or 60 km/h, daylight hours, arterial shopping precincts and complex road environments (O'Hern et al., 2015). It is likely that road crossing treatments which focus on these areas of difficulty and high-risk road environments will have safety benefits for all vulnerable pedestrians, regardless of age or type of disability.

Part 2 described current pedestrian crossing options used in WA and the strengths and weaknesses of these options for the safety of older pedestrians and those with disabilities. Overall, there are a very wide range of pedestrian facilities currently used in WA and a number of these provide good, safe crossing options for vulnerable pedestrians. For example, at mid-blocks Puffin crossings which can extend the length of the crossing phase as needed provide a particularly safe, albeit expensive crossing option for these pedestrians (Department of Transport, 2016). Under certain conditions, pedestrian refuges or zebra/ wombat crossings may also provide safe mid-block crossing options for vulnerable pedestrians (Department of Transport, 2016). At signalised intersections, parallel crossings with full protection by vehicle signals provide a high level of protection for these groups, as they do not have to watch for turning vehicles (Department of Transport, 2016). Evidence also suggests that countdown timers at signalised intersections improve safety for older and slower pedestrians by assisting them in their decision making about whether it is safe to begin a road crossing (Lipovac et al., 2013). The research reviewed suggests that pedestrian signal phase timing may be inadequate for many older pedestrians and those with disabilities to complete a safe road crossing (Romero-Ortuno et al., 2010), so extending these phases or investigating pedestrian detection technology could be essential for increasing the safety of an ageing population. Finally, along sections of road with high pedestrian activity, currently used methods including reduced speed limits, variable speed limits, traffic calming and reduced traffic volumes are known to be highly effective in reducing crashes and crash severity among pedestrians (Oxley & Fildes, 1999), including older pedestrians and those with disabilities.

Part 3 reviewed the pedestrian crossing options used in other countries as well as new emerging options. Alternative mid-block crossing options included speed humps on approach to zebra crossings, use of additional lights, signage and vehicle stop lines at zebra crossings and the *"smart"* Starling crossing. Signalised intersection crossing options included the SafeWalk and C-Walk pedestrian detection systems, Singapore's *"Green Man"* scheme, in-ground pedestrian lights and pedestrian switch pads. Different types of on-person technology such as vibrotactile wristbands and phone apps are emerging to assist with safe road crossing, however these are currently only in the early development stage. A limitation of this review was that the cost of each treatment was not readily available, making it difficult to compare alternative safe crossing options in terms of potential cost-effectiveness.

## 4.1 Recommendations

This section makes recommendations for the continued use of specific existing crossing options, further research and the types of alternative pedestrian crossing options that would be useful to trial in WA. This encompasses Phase 1 of the project. The proposed Phase 2 of the project would involve identifying a suitable Local Government Association (LGA) to trial the alternative options, selecting appropriate trial sites and evaluating the effectiveness of the crossing option in terms of improving road safety for pedestrians, focusing on older pedestrians and those with disabilities.

### Existing pedestrian crossing options in WA

- ***Recommendation 1:*** Continued implementation of existing safe pedestrian crossing options at mid-block locations including Puffin crossings, zebra or wombat crossings and pedestrian refuges, as appropriate.

- ***Recommendation 2:*** Continued implementation of existing safe pedestrian crossing options at signalised intersections including parallel pedestrian crossing phasing with full protection by vehicle signals and countdown timers.
- ***Recommendation 3:*** Continued implementation of existing strategies to improve pedestrian safety along sections of road which have complex traffic environments including lower speed limits, variable speed limits, traffic calming and traffic volume reduction methods.

  For recommendations 1-3, the safety of older pedestrians and those with disabilities could be improved either by more widespread implementation of these existing safer crossing options at mid-blocks, signalised intersections and along road sections, or through targeted treatment of specific areas with higher numbers of vulnerable pedestrians.

**<u>Further research</u>**

- ***Recommendation 4:*** Conduct further research into whether current pedestrian signal phase timing in WA is adequate for older pedestrians and those with disabilities to safety complete the road crossing at signalised intersections and signalised pedestrian crossings.

  International research indicates that current pedestrian signal phase timing may be inadequate for many older and slower pedestrians, however no research has been conducted in Australia. Options for making pedestrian signal phases safer include extending pedestrian signals across WA or at selected locations, or installation of pedestrian detection technology.

**<u>Alternative pedestrian crossing options</u>**

- ***Recommendation 5:*** Trial and evaluate the effectiveness of providing additional treatments at zebra or wombat crossings located at mid-blocks. These treatments include speed humps on approach to the crossing, flashing beacons, additional signage for vehicles and vehicle stop lines.

  Research from Europe and North America has reported positive safety outcomes from the installation of these treatments at mid-block crossings. These additional treatments may have the potential to improve safety for older pedestrians and those with disabilities in WA.

- ***Recommendation 6:*** Trial and evaluate the effectiveness of providing additional treatments at signalised intersections. These include pedestrian detection technology (e.g. SafeWalk/ C-Walk) which can extend the pedestrian crossing phase as required and swipe card technology (e.g. The *"Green Man"* Scheme) which can extend the pedestrian phase by a set amount of time.

  Treatments which extend the crossing phase for pedestrians at signalised intersections could potentially improve safety for older pedestrians and those with disabilities, who often walk or travel at a slower pace. To date, no safety evaluations of these treatments have been undertaken.

### 4.2 Prioritisation of pedestrian crossing options for Phase 2 trial

Recommendations 5 and 6 highlighted alternative pedestrian crossing options which may have the potential to improve the safety of older pedestrians and those with disabilities in WA. From the existing evidence, alternative pedestrian crossing treatments can be prioritised for trialling in WA as follows:

1. Pedestrian detection technology at signalised intersections (e.g. SafeWalk/ C-Walk) which can extend the pedestrian crossing phase as required;
2. Additional treatments at zebra or wombat crossings located at mid-blocks including speed humps on approach to the crossing, flashing beacons, additional signage for vehicles and vehicle stop lines;
3. Swipe card technology which can extend the pedestrian phase at signalised intersections by a set amount of time. (Note: this treatment has been prioritised third since it has extensive administrative requirements due to set up and distribution of a swipe card system).

In order to select appropriate sites in WA to trial these pedestrian crossing treatments, a feasibility study would need to take place as the initial step of Phase 2. This would involve obtaining support from one or more Local Government Authorities, determining areas within the LGA that have high numbers of older pedestrians and those with disabilities and obtaining advice from Main Roads WA on the suitability of specific sites in those areas for the pedestrian crossing treatments.

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