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Crash and injury risk of older pedestrians and identification of measures to meet their mobility and safety needs

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Abstract

Crashes involving pedestrians are frequently serious in nature and many involve older adults. While the majority of older adults use the road-transport system without injurious consequences, many still experience problems as pedestrians. The growing complexity of the road environment, particularly the dominance of vehicles, high speed and traffic volumes on many roads places high demands on an older person’s adaptability, whilst ageing can diminish the capacity to cope with many traffic situations. This paper draws on a large research program on older pedestrian safety to discuss the issues surrounding older pedestrians’ safe mobility. First, the contributing factors to crash and injury risk are discussed, with a focus on the effects of functional and health declines on road crossing skills. Particular reference is made to the effects of age-related physical, perceptual and cognitive limitations, onset of medical conditions, and ability to compensate for these changes and environmental factors including the road environment and vehicle design. Second, a number of measures to improve the safe mobility of older pedestrians are identified. The paper highlights ‘best-practice’ recommendations to increase the comfort and safety of pedestrian environments including the adoption of a system-wide approach that incorporates behaviour and education programs (such as increased awareness of age-related changes, training and adoption of safe walking practices), improvements to vehicle design (such as improved frontal design to provide ‘optimum’ pedestrian crash conditions), as well as improvements to infrastructure, road design and operation of the road-transport system in high pedestrian activity areas (such as speed reduction, separation of travel modes and reductions in traffic complexity). The knowledge gained from this research

program is an important step in developing appropriate measures to reduce pedestrian trauma. Meeting the needs of older people in the future will require a comprehensive strategy, one which will encompass policy at all levels and a fundamental reconsideration of the way in which the traffic and transport system functions to ensure a safe, comfortable and convenient road environment in which to walk.

Biographies

Dr Jennifer Oxley:

Dr Oxley's main area of expertise is vulnerable road user safety and mobility. She manages a range of research projects addressing: the implications of functional performance limitations on child, intoxicated and elderly pedestrian and driver performance and safety; gender effects on travel patterns, driving experience and crash risk; assessing fitness to drive; reduction and cessation of driving; and, countermeasure development.

Dr Judith Charlton:

Dr Charlton is responsible for managing the older driver research program at the Accident Research Centre. Her research interests focus on older driver safety and mobility issues and the influence of age-related changes in cognition and perception on driver behaviour. Current projects include the evaluation of screening instruments for assessing functional abilities in potentially at-risk drivers; older driver self-regulation; and vision conditions and fitness to drive. She serves on several national and international committees, including the Scientific Committee of the Association for the Advancement of Automotive Medicine, the Australasian College of Road Safety (Victoria) and Brain Foundation Victoria.

Mr. Bruce Corben:

Mr. Corben has managed many research projects, mainly in the area of road infrastructure safety, over a period of some thirteen years at MUARC. Key areas of his research program include managing road and traffic engineering safety research projects such as: developing and evaluating countermeasures for a range of hazardous pedestrian conditions in Victoria, including alcohol-affected pedestrians; developing new solutions for intersection trauma; evaluating the effectiveness of accident 'black spot' programs to improve investment strategies; evaluating the effectiveness of countermeasures for roadside hazards, particularly barrier systems, and developing treatment programs.

Prof. Brian Fildes:

Professor Fildes is the Chair of Road Safety at the Accident Research Centre. He has particular interests in occupant protection, driver perception and injuries to older people, both on the road and in the home. He has been instrumental in helping government agencies implement a number of new injury prevention countermeasures and programs as well as evaluating real world crash performance for the automotive industry.

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Pedestrian crashes are frequently severe in nature and represent a major road safety problem world-wide. Australia reports high proportions of older pedestrian deaths and serious injuries but lower proportions of minor injury crashes, as do European countries and the USA (ATSB, 2006; Öström & Eriksson, 2001; Campbell et al., 2004). Thirty eight percent of all pedestrian fatalities in Australia in 2005 and 36 percent of all pedestrian serious injuries in 2002 were adults aged 60 years or over (ATSB, 2006).

Risk factors

The over-representation of older adults in pedestrian crashes may reflect, in part, their frailty – once involved in a crash (even a moderate crash) older pedestrians are more likely to sustain fatal or serious injuries than younger pedestrians (Mitchell, 2000; National Highway Traffic Safety Administration [NHTSA], 2001), and more likely to take longer than younger adults to recover from their injuries (Augenstein, 2000; Cunningham et al, 2001). There have been various attempts to quantify the impact of frailty when explaining older drivers' crash risk. As a recent example, it was estimated that fragility accounted for between 60 to 90 percent of the excess death rates amongst older drivers, with excessive crash involvement due to 'other factors' being largely restricted to drivers aged 80 years or older. For these older male and female drivers, 'other factors' accounted for 37 percent to 43 percent of their overall fatal crash involvement (Li et al., 2003). These 'other factors' may include behavioural aspects and road and vehicle design. These estimates most likely also apply to older pedestrians.

Behavioural factors

Safe walking and making decisions about when it is safe to cross roads, at least in some situations, are complex tasks that demand a host of age-sensitive functions such as processing and integration of multiple sources of information and quick interpretation of the most important stimuli in fast-moving and busy traffic.

Most people experience some level of functional decline as they age, particularly in sensory, physical and cognitive areas. Much of the literature, therefore, is concerned with the functional consequences of medical conditions and declines in these abilities and resulting problems in coping with certain traffic situations. While there is little doubt that the onset of age-related changes can affect many areas of daily living, it is important to recognise that older road users are generally considered to be safe and cautious and, indeed, the majority of older road users do use the road-transport system without injurious consequences. There is evidence to suggest that older road users self-regulate their travel patterns, adopting cautious behaviours and may well do this as a means of adapting to changing health and skills (Charlton et al., 2006; Smiley, 2004; Organisation for Economic Co-operation and Development [OECD], 2001). On the other hand, there may be some older road users who are less able to compensate and may be at increased risk. This may be due to accumulation of age-related losses to a point where they overwhelm the normal attempts at compensation, particularly when demands are significant or complex (Yanik & Monforton, 1991), and where there is a reduced awareness of the impact of ageing on task performance (Elliott et al., 1995; Holland & Rabbitt, 1992, Marottoli & Richardson, 1998).

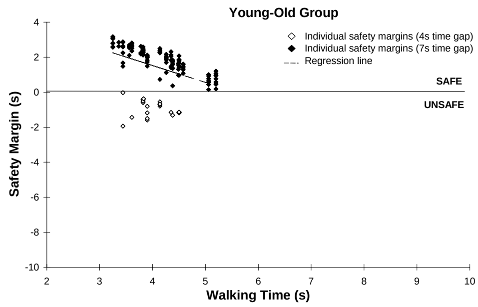
Sheppard and Pattinson (1988) described some of the difficulties in crossing roads, as reported by 473 older pedestrians who had been involved in a pedestrian-vehicle crash. Failure to see the vehicle that struck them, or to see in time to take evasive action, was reported by almost two-thirds of respondents. When asked about ability to judge speeds of approaching cars, one-third said they could 'not do this well at all'. In around 40% of cases, respondents indicated that the location of their crash was a difficult place to cross (e.g., hard to see, confusing, and fast-moving traffic). Data from Sweden also indicate that more than one-third of older road users find it difficult to be pedestrians (Ståhl, 1992; Ståhl et al., 1993). These included: fear of being involved in a crash caused by personal limitations; fear of falling due to poor maintenance of roads; difficulty gathering information in complicated and changing traffic situations.

The evidence suggests that simultaneous deterioration of several relevant functions and/or specific functional deficits linked to illnesses (especially those that lead to cognitive deterioration) increase crash risk considerably (OECD, 2001). A number of observational and experimental studies provide evidence that perceptual, cognitive and physical factors play some role in the performance and safety of older pedestrians. For example, there are many reports providing strong evidence that cognitive and executive function declines and onset of chronic diseases with associated impairments are powerful predictors of walking ability and falling (Bootsma-van der Wiel et al., 2002; Bergland & Wyller, 2004; DiFabio et al., 2005; Shumway-Cook & Woollacott, 2000).

Furthermore, several studies have reported that older adults make risky crossing decisions and experienced difficulties selecting safe gaps to accommodate for their slower walking speeds in complex traffic environments (Carthy et al., 1995; Oxley et al., 1997; 2005). Oxley and colleagues (1997, 2005) provided evidence of poor gap selection amongst the oldest and slowest walkers in a series of observational and experimental studies, particularly in fast moving traffic and complex two-way traffic.

Experimental data showed that many oldest and slowest walkers decided to cross in gaps when they should have said ‘no’ based on their walking speed and decision time. Figure 1 shows distributions of individual safety margins by young (30-45 year old), young-old (60-69 year old) and old-old (75+ year old) adults in critical time gaps of 4s and 7s.

For all age groups, the safety margin decreased with increasing walking and decision times and this was particularly so for the oldest group. The distribution of the young group shows little variability and relatively safe crossing decisions. Only 19 percent of young adults indicated they would have crossed in an unsafe manner and the unsafe crossings for this group were only marginally unsafe (generally falling between 0 and –1s of safety margin). In contrast, the distributions of the older groups showed more variability, especially that of the oldest group. While only 18 percent of the young-old group indicated unsafe crossing, a much larger proportion (70%) of



the old-old adults did so. The unsafe responses of this group extended to –10s.

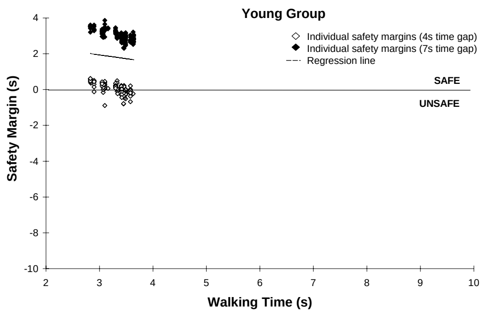


Figure 1: Distribution of safety margins for all positive crossing decisions at 4s and 7s time gaps plotted as a function of walking time.

Moreover, Oxley et al. (2001) examined the effect of functional performance on road-crossing decisions using a selection of six functional assessments designed to assess visual, attentional, cognitive and physical abilities and included tests of contrast visual acuity, the Digit-Symbol Test, Trail Making Tests A and B, the MOMSSE and the timed 'Get-Up-and-Go' Test. All test of functional performance were predictors of correct 'yes' responses, with poor performance on these tests being associated with the probability of making an incorrect (or unsafe) 'yes' response. These findings implicate age-related cognitive and executive function declines in reduced pedestrian performance.

Gorrie and her colleagues (2004) examined neurodegenerative change (neurofibrillary tangles [NFT], a pathological hallmark of Alzheimer's Disease) within the brains of 51 fatally injured older pedestrians compared with 49 non-pedestrian fatalities and found significantly higher NFT scores amongst fatally injured pedestrians compared with fatally injured non-pedestrians (37% vs. 14%). Moreover, pedestrians with higher NFT were over-involved in crashes at intersections, more likely to have walked into the path of an oncoming vehicle, and were not on a designated crossing facility, compared with those with lower NFT scores. While these findings do not report on crash circumstances, responsibility or exposure of non pedestrian participants in the study, they point to a lack of good judgement about when and how to cross roads safely, implicating cognitive decline as a risk factor for older pedestrians.

Vehicle design

An important factor in the severity of pedestrian crashes is the impacting vehicle, particularly it's mass and frontal structure design. Maki et al. (2003) reported that pedestrians' heads typically strike the vehicle on the rear part of the bonnet or on the windscreen, and argued that the front-end geometry of vehicles greatly affects the severity of head injuries. Moreover, there is great concern that the increasing trend of large recreational vehicles, SUVs, mini vans and four-wheel-drive vehicles in the vehicle fleet in many countries is likely to produce more severe injuries to pedestrians. Even at a given impact speed, pedestrians struck by SUVs, pickups or vans, with their high bumpers and blunt frontal profiles, are likely to contact initially at the upper leg or abdomen and incur a serious head injury. Lower bumpers of passenger cars mean that struck pedestrians are more likely to incur a lower leg injury. In addition, heavy braking in passenger cars results in the more dramatic tilting downward of the front of the vehicle, compared with larger SUV's, vans and four-wheel drives (Ballesteros et al., 2004; Lefler & Gabler, 2004; Mizuno & Kajzer, 1999; Simms & O'Neill, 2005).

The fitting of rigid bull-bars without deformable padding to many large vehicles is also of great concern to pedestrian safety. Tubular metal bull-bars without deformable padding are very stiff and concentrate crash forces in a small area and are more likely to seriously injure pedestrians in a collision than if the vehicle were not fitted with a bull-bar (Land Transport Safety Authority [LTSA], 2003; UK Department of Transport, 2003; Anderson et al., 2006).

The road environment

The safety of older pedestrians may well be compromised to a large extent by the design and operation of the road-transport system. Many of the problems for pedestrians stem from the fact that the current road system is generally designed for vehicles, and mainly for young, fit and healthy road users and, for the most part, seems to be unforgiving for older vulnerable road users. Dominant attitudes by drivers, failure to acknowledge the rights of pedestrians and fast speeds of drivers in areas of high pedestrian activity greatly increase the potential for crashes and, more importantly, the injury consequences once a collision occurs. Moreover, older pedestrians appear to experience problems in situations that demand efficient cognitive processing, fast responses and quick actions such as at intersections, on multi-laned roads, fast moving traffic, at crossing facilities that do not allow enough time for slower walkers, and on congested, poorly maintained and uneven footpaths and roads.

One of the major problems for pedestrians is high vehicle speed. Higher driving speeds reduce predictability of the vehicle for pedestrians and reduce a driver's ability to control the vehicle, negotiate and manoeuvre around obstacles and other road users. Higher speed also increases the distance a vehicle travels while the driver reacts to a potential collision and increases the minimum possible braking distance, thereby reducing the time available to avoid a collision. More importantly, the probability of injury and the severity of injuries that occur in crashes in general increase exponentially with vehicle speed – to the power of four for fatalities, three for serious injuries and two for casualties (Nilsson, 1984). Figure 2 shows the critical relationship between vehicle impact speed and injury severity. Pedestrians struck at 30 km/h, on average, have a 10 percent probability of death, at 40 km/h a 25 percent probability of death, and by 50 km/h over 80 percent of pedestrians can be expected to die from the impact (Anderson et al., 1997). Even crashes involving younger pedestrians are likely to result in serious injury at relatively low impact speeds, but, given their increased frailty, older pedestrians are likely to suffer more severe injuries at lower impact speeds (Davis, 2001).

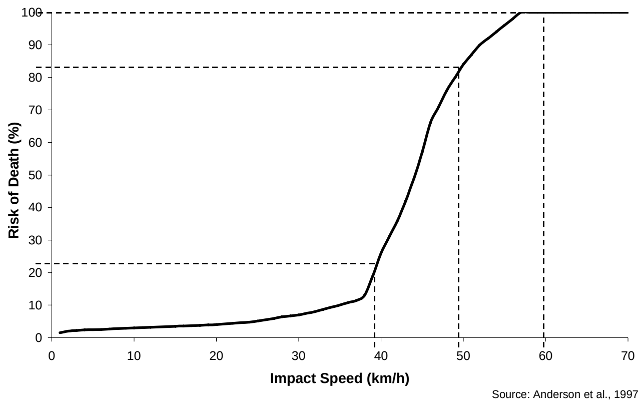


Figure 2: Risk of pedestrian death as a function of vehicle impact speed

Complex environments pose many dangers for older road users as drivers, pedestrians and cyclists and this is evidenced in their over-represented in crashes at complex intersections and when traffic volumes and speeds are high (OECD, 2001; Staplin et al., 2000). For older pedestrians, poor design features such as inadequate sight distance, lack of refuge islands, lack of signals to control turning movements of vehicles, poor conspicuity of signals and signs, poor channelisation and delineation of travel lanes are all likely contributors to increased crash risk. Wide, multi-lane roads are especially hazardous for older pedestrians, most likely due to their slower walking speeds and diminished abilities to handle complex traffic conditions (Oxley et al., 1997; Campbell et al., 2004).

Further, few facilities are designed specifically for the special needs and capabilities of older pedestrians. Crossing phases (both walk and clearance) at signalized pedestrian crossing facilities are commonly too short for slow walking pedestrians and can be confusing for many older adults (Catchpole, 1998; Guerrier & Jolibois, 1998; Tarawneh, 2001). For example, in the US, current walking speed used for the design of intersections is 1.22m/s (Federal Highway Administration [FHWA], 1988). On average, older pedestrians walking speed is in the order of 0.91m/s to 1.00m/s (Knoblauch et al., 1996; Tarawneh, 2001; Hauer, 1988). This value is clearly inadequate for many older pedestrians to complete crossing the road and there have been many calls to extend walking phases to accommodate these slower walking speeds.

Surfaces of roads and footpaths cause problems for older pedestrians (Fildes et al., 1994; Björnstig et al., 1997). Other problems include uneven paths and road surface, high kerbs, narrow and poorly maintained paths (particularly in winter when covered with ice or snow), obstacles on the path, congestion on the footpath (parked cars and other footpath users), and poor lighting.

Some solutions

In order to identify best practice solutions, it is important to consider the philosophies and practices of countries that address safety in an innovative and effective way and those that emphasise the vulnerability of particular road user groups, such as the Swedish ‘Vision Zero’, the Dutch ‘Sustainable Safety’ and the recently adopted Australasian ‘Safe System’ approaches. Meeting the mobility and safety needs of older people in the future can be achieved by managing crash occurrence and energy by providing safer vehicles, safer roads and safer road users and recognising the interactions between these three components in a comprehensive way.

Safer road users – behavioural and education options

In recent years, there has been a major push to promote walking in urban areas, particularly in Europe, Australia and New Zealand. Initiatives such as the European PROMISING, WALCYNG, and ADONIS projects as well as the Victorian ‘Go For Your Life’ campaign promote alternative forms of transport, particularly walking and cycling. While the main emphasis is on enhancing health and mobility of particular groups, their safety should also be taken into account. It is paramount that safe and comfortable walking environments are provided in conjunction with this advance to increase walking and cycling as important modes of transport.

In addition, there are a number of initiatives that aim to raise the awareness of pedestrian safety both amongst pedestrians themselves and drivers. Pedestrian safety programs aim to promote the adoption of safe walking practices such as reducing their exposure to risk, maintaining function and practice of appropriate behaviour to compensate for age-related changes, maintenance of safe driving for as long as possible, updating knowledge of road regulations, wearing clothes and devices that increase conspicuity, and making eye contact with drivers. Examples of programs aimed at older pedestrian safety include the 'Walk Alert Pedestrian Safety' program in the US and the 'Walk-With-Care' program in Victoria, Australia.

Educational, awareness and behaviour change programs are vital to the success of improving pedestrian safe mobility, particularly to increase the adoption of safe walking practices. While their effects on crash risk are rarely evaluated, such programs are regarded as an essential component of any strategy and are, reportedly, well-received by many older community members. Moreover, it appears that programs that include both educational and engineering components can work well (Blomberg & Cleven, 1998; Kent & Fildes, 1997).

Safer vehicles – frontal design and Intelligent Transport System (ITS) technologies

Since the majority of pedestrian injuries and deaths are the result of collisions with vehicles, improvements in crash protection should be a priority. Pedestrian protection features built into vehicles can be very effective in preventing injuries in impacts even at moderate speeds. Over the past three decades progress has been made in the development of test procedures for use in assessing the degree of pedestrian protection afforded by new vehicles. A set of component tests have been designed representing the three most important mechanisms of injury, namely i) lower leg against the bumper, ii) upper leg against the bonnet edge, and iii) head against the bonnet and top wing. The European Enhanced Vehicle Safety Committee (EEVC) proposed that, by the year 2010, all new vehicles should comply with test specifications and, should these be accepted, there will be a 20 percent reduction in pedestrian deaths. Encouragingly, the European New Car Assessment Programme (Euro NCAP) reported the first car to be awarded the maximum four stars for pedestrian protection (without compromising the protection of vehicle occupants). This vehicle detects when a pedestrian has been struck and activates a 'pop-up' bonnet to give greater clearance between the bonnet and the rigid structures of the engine below (www.euroncap.com).

In addition, there are suggestions that modifications to the front and side design of SUV's vans and four-wheel-drive vehicles, particularly the design of bull bars can significantly reduce the harm of heavy vehicle-pedestrian crashes (Desapriya & Pike, 2005). Anderson and his colleagues (2006) assessed a range of common types bull bars in terms of design and materials. They found that polymer bull bars recorded the lowest impact severity and appeared to be less hazardous than the bonnet leading edge of the vehicles to which they were attached. Moreover, the impacts recorded by the steel bull bars were significantly more severe (and often exceeded the measuring range of the test equipment). Aluminium/alloy bull bars were significantly more hazardous to a pedestrian than the front of the vehicle, but to a lesser extent than steel bull bars.

There is active discouragement by governments of the manufacture of rigid and aggressive bull-bars and encouragement for the design and manufacture of plastic or composite metal/plastic bull-bars that are relatively soft and offer impact absorption protection and bull-bars that are low profile and contour-hugging (with no pointed or sharp edges), generally conforming to the shape of the front of the vehicle (Hong Kong Transport Department, 2003; UK Department for Transport, 2003; LTSA, 2003).

There are a number of ITS in-vehicle technologies that have the potential to reduce crash and injury risk for pedestrians. There are speed-alerting and limiting devices, devices that detect hazards on the road and warn drivers or intervene to prevent a collision (vision enhancement technologies and rear collision warning and avoidance technologies), and devices to increase the conspicuity of vehicles to pedestrians such as daytime running lights. Many of these systems are still under development and require further work to assess their effectiveness, however, preliminary studies are promising. Substantial reductions of excessive speeding, compliance with speed limits, increased awareness of vulnerable road users and acceptance by drivers of speed alerting and limiting devices have been found (Brookhuis & de Waard, 1999; Várhelyi, 2001). Studies on the effectiveness of daytime running lights on crash rates reveal reductions in multi-vehicle daytime crashes of between 8% and 29% (European Transport Safety Council [ETSC], 1999). No data, however, are available on the effect of these technologies on crashes involving vulnerable road users.

Safer roads – providing a more forgiving environment

Engineering countermeasures have the potential to quickly and effectively create a safer and more forgiving travel environment for vulnerable road users.

Safer speeds: Pedestrians are only safe when speeds are low, in the order of 30 to 40 km/h (ETSC, 1999; Wramborg, 2006; Yeates, 2001). At these speeds, most potential collisions can be recognised and avoided, and, if a collision does occur, damage and injury should be light to severe, but rarely fatal. Even small reductions in vehicle speeds have been shown to result in substantial reductions in serious injury pedestrian crashes (Anderson et al., 1997; Haworth et al., 2001). Moreover, a lower speed environment can provide older pedestrians with a simpler task in which to select safe gaps in the traffic.

Most OECD countries have adopted general urban speed limits of 50 km/h and some permit zoning at lower speeds in residential and shopping areas and school zones. Most Australian States have introduced the 50 km/h speed limit on residential streets and recent data have shown significant crash and injury reductions in road trauma in these areas in New South Wales and Victoria (Haworth et al., 2001).

Moderation of vehicle speeds in areas of high pedestrian activity can be achieved through traffic-calming measures and ITS applications. Traffic-calming measures act to make drivers more attentive to their surroundings and drive more slowly or appropriately for the surroundings and include physical modifications to the roadway (such as pavement narrowing, refuge islands, alterations to the road surface, speed humps, roundabouts, gateway treatments and perceptual countermeasures such as painted chicanes and altered road surfaces). In 'best-practice' designs, these measures are used to form an overall design concept that pedestrians and cyclists have priority, and that high-speed through-traffic is discouraged. These are now common in Europe, and becoming popular in other countries, with reports of success (ETSC, 1999; Macauley et al., 2004).

Out-of-vehicle ITS applications have the potential to enhance speed limit compliance and these include dynamic messaging (active speed warning and variable message signs). Corben et al. (2001) reported that such technologies act to reduce average vehicle speeds by between four and eight km/h. They calculated some very attractive benefit-cost ratios (BCRs) associated with the use of these displays on different road and environment types and found BCRs ranging from 7.7 to around 45, dependent on environment.

Safer walking environments: Providing a safe and comfortable walking environment for pedestrians can effectively improve safety and mobility for pedestrians and can be achieved through separation of pedestrians and vehicles, simplification of the traffic environment, and improvements to pedestrian facilities.

Separation of vehicular and non-vehicular traffic – heavy and fast moving traffic flows are major deterrents to walking and much of the literature stresses the importance of separation of transport modes. Provision of vehicle-free zones is an extremely effective way of improving safety and mobility for pedestrians. Even partial separation in the form of vehicle-restricted zones can be beneficial. Vehicle-restricted areas are used worldwide and usually involve the use of traffic-calming measures and environmental beautification to deter or slow down vehicular traffic.

Barrier fencing and guardrails on road edges and between opposing lanes of traffic are effective at limiting access to the road at hazardous mid-block locations, and good placement and design of fencing and guardrails is essential for compliance. In some locations, alternative types of barriers (such as garden beds, raised planter boxes and outdoor seating) can be used, both for aesthetic reasons and to achieve greater compliance – they may realize higher acceptance from pedestrians because they appear as natural elements of the streetscape, rather than overt attempts to re-direct pedestrians from their most convenient path (Oxley et al., 2004).

Grade-separation of crossings is another excellent way to eliminate conflict between vulnerable road users and vehicles, however, these treatments have not met with much success, particularly for older pedestrians, because of the difficulties walking up and down stairs or long ramps, and security issues. Nevertheless, footbridges or subways that are designed to keep pedestrians on their natural desired line while motorists undergo the changes in grade and level, and that have no steps or troublesome ramps may be effective (ETSC, 1999).

Footpaths are an integral part of the pedestrian transport network and safety and mobility can be improved with designs such as tactile paving, flexible tiles, ramps, high contrast surface painting and regular maintenance. Collisions between pedestrians and cyclists can occur on shared footpaths (Oberg et al., 1996) and important to improve attitudes and mutual respect through education and physical measures such as lane markings and speed humps to separate these modes and reduce cyclist travel speeds.

Simplification – complex traffic situations include intersections, wide, multi-laned roads, and busy, fast moving traffic and should be designed to offer sufficient time for older pedestrians to assess the traffic make an appropriate decision and perform the various tasks required (Hagenzieker, 1996; Oxley et al., 1997; Dijkstra et al., 1998).

The conspicuity of pedestrians by drivers should be increased at intersections. This can be achieved by provision of a leading green (usually of around 3 s) whereby pedestrians are able to commence crossing before vehicles, particularly those turning, can enter the intersection (Griebe et al., 1998; Staplin et al., 2001). The installation of large and bright (e.g., fibre optic) ‘give way to pedestrian’ signals can overcome some problems (Catchpole, 1998). In addition, holding lines for vehicles could be set back farther from the crosswalk (Retting, 1993), crosswalks can be painted with a high contrast colour (Oxley et al., 2001), and footpaths could be widened and extended further into the carriageway (Ribbens, 1996).

Roundabouts are associated with major safety benefits for vehicle occupants (Newstead & Corben, 2001; Persaud et al., 2001). While the safety benefits for vulnerable road users are less clear, particularly because of inconvenience and complexity, they do result in more moderate vehicle speeds which can benefit pedestrian safety. There are ways to make them safer and more convenient for pedestrians including lane reduction from multi-lane to single-lane, building shared footways connected to pedestrian crossings close to the roundabout, making the splitter islands as large as possible, banning parking near roundabout entries to remove visual obstructions, placing signs and vegetation in such a way that pedestrians are not obscured, providing adequate street lighting at the entry to roundabouts as well as the entire carriageway, and ensuring that vehicle speeds are reduced on the approach to the roundabouts by the use of adequate deflection and traffic-calming measures (Dijkstra et al., 1998; Jordan & Jones, 1996; Lange, 2000).

Median islands/refuges offer benefits for older pedestrians (Hagenzieker, 1996; Oxley et al., 2004; Bergman et al., 2002). They separate traffic directions, allowing pedestrians to stage the road cross in two phases (only needing to check for traffic in one direction at a time thus decreasing the cognitive and physiological demand on them), provide a refuge to rest after crossing the first half of the road and before commencing the second half, and reduce vehicle speeds.

Other improvements – crossing facilities are generally considered a safety feature, however, there are some improvements that can be made to assist older pedestrians. First, facilities could be located at appropriate places for pedestrians to use – pedestrians prefer to take the most direct route to their destination and are unlikely to walk very far from their intended path to a crossing point far away, especially if they experience difficulty walking (OECD, 2001). Second, longer and less confusing walk and clearance phases are required for slower walking older pedestrians. The walking speed values (approximately 1.2 m/s) used for design and operation standards (FHWA, 1988; Austroads, 1995), are clearly too fast for many slow-walking older pedestrians and there have been calls to extend walking phases, especially in areas where there are high numbers of older walkers (Guerrier & Jolibois, 1998; Tarawneh, 2001; Knoblauch et al., 1996). A reportedly successful innovation is the optical detection system known as the Puffin (**P**edestrian **U**ser **F**riendly **In**telligent) or Pussycats (**P**edestrian **U**rban **S**afety **Sy**stem and **C**omfort **a**nd **T**raffic **S**ignals) crossing system. These result in reduced red light violations by pedestrians (Catchpole, 1998; Cairney & Green, 1999; Reading et al., 1995), and reduced conflict, stress and confusion (Dijkstra et al., 1998). There is some concern that these facilities may result in a short increase in delay to vehicular traffic, however, this appears to be compensated for by the automatic cancellation and extension mechanisms when pedestrian demand is low (Retting et al., 1999).

Conclusion

The safety and mobility of vulnerable road user groups is an important issue and should be a priority of any transport policy. This paper has identified measures to address the safe mobility of older pedestrians and these consist of i) safer road users, ii) safer vehicles, and iii) safer roads. The strategic application of initiatives within innovative approaches will enable current and future older pedestrians to continue walking in relative safety and ensure adequate access to services and facilities.

References

Anderson R, McLean A, Farmer M, Lee B, & Brooks C. (1997). Vehicle travel speeds and the incidence of fatal pedestrian crashes. *Accident Analysis and Prevention*, 29(5), 667-674.

Anderson R, van den Berg A, Ponte G, Streeter L, & McLean A. (2006). Performance of bull bars in pedestrian impact tests. (Report No. CASR020). Adelaide, Australia: Centre for Automotive Safety Research, University of Adelaide.

Augenstein J. (2000). Article in the Los Angeles Times, July 31.

Australian Transport Safety Bureau [ATSB] (2006) Road deaths Australia, 2005 Statistical summary. Downloaded from www.atsb.gov.au

Austroads (1995). Guide to Traffic Engineering Practices: Pedestrians (Part 13). Sydney, Australia: Austroads.

Ballesteros M, Dischinger P, & Langenberg P. (2004). Pedestrian injuries and vehicle type in Maryland, 1995-1999. *Accident Analysis and Prevention*, 36(1), 73-81.

Bergman A, Gray B, Moffat J, Simpson E, & Rivara F. (2002). Mobilizing for pedestrian safety: an experiment in community action. *Injury Prevention*, 8, 264-267.

Bergland A, & Wyller T. (2004). Risk factors for serious fall related injury in elderly women living at home. *Injury Prevention*, 10(5), 308-313.

Björnstig U, Björnstig J, & Dahlgren A. (1997). Slipping on ice and slow – elderly women and young men are typical victims. *Accident Analysis and Prevention*, 29(2), 211-215.

Blomberg R, & Cleven A. (1998). Development, implementation and evaluation of a pedestrian safety zone for elderly pedestrians. (Report No. DOT HS 808 692). Washington DC, USA: National Highway Safety Administration and Federal Highway Administration, US Department of Transportation.

Bootsma-van der Wiel A, Gussekloo J, de Craen A, van Exel E, Bloem B, & Westendorp R. (2002). Common chronic diseases and general impairments as determinants of walking disability in the oldest-old population. *Journal of American Geriatrics Society*, 50, 1405-1401.

Brookhuis K, & de Waard D. (1999). Limiting speed, towards an intelligent speed adapter (ISA). *Transportation Research Part F*, 16, 1-10.

Cairney P, & Green F. (1999). The implications of intelligent transport systems for road safety. (RC No. 7032). Melbourne, Australia: ARRB Transport Research.

Campbell B, Zegeer C, Huang H & Cyneki M. (2004). A review of pedestrian safety research in the United States and abroad. (Report No. FHWA-RD-03-042). Washington DC, USA: US Department of Transportation.

Carthy T, Packham D, Salter D, & Silcock D. (1995). Risk and safety on the roads: The older pedestrian. Basingstoke, UK: AA Foundation for Road Safety Research.

Charlton J, Oxley J, Scully J, Koppel S, Congiu M, Muir C, & Fildes, B. (in press). Self-regulatory driving practices amongst older drivers in the ACT and NSW. Melbourne, Australia: Monash University Accident Research Centre.

Catchpole J. (1998). Flexible signal timing to suit elderly and disabled pedestrians. *Proceedings of the Conference on Pedestrian Safety*, (pp. 147-157), Melbourne, Australia.

Corben B, Lenné M, Regan M, & Triggs T. (2001). The cost-benefits of ITS technologies to enhance speed compliance. Proceedings of the Road Safety Research, Policing, and Education Conference, Melbourne, Australia.

Cunningham C, Howard D, Walsh J, Coakley D, & O'Neill D. (2001). The effects of age on accident severity and outcome in Irish road traffic accident patients. *Irish Medical Journal*, 94, 169-171.

Davis G. (2001). Relating severity of pedestrian injury to impact speed in vehicle-pedestrian crashes. *Transportation Research Record*, 1773, 108-113.

Desapriya E, & Pike I. (2005). Sports utility vehicles and older pedestrians: Achieving compatibility in motor vehicle crashes. *British Medical Journal*, 331, 966-967.

DiFabio R, Zampieri C, Henke J, Olson K, Rickheim D, & Russell M. (2005). Influence of elderly executive cognitive function on attention in the lower visual field during step initiation. *Gerontology*, 51(2), 94-107.

Dijkstra A, Levelt P, Thomsen J, Thorson O, Van Severen J, Vansevenant P, Nilsson, P, Jørgensen E, la Cour Lund B, & Laursen J. (1998). Best practice to promote cycling and walking (ADONIS). Research project for the EU Transport RTD programme, European Commission. Copenhagen, Denmark: Directorate General for Transport, Danish Road Directorate.

Elliott D, Elliott B, & Lysaght A. (1995). Older driver risks and countermeasures: Source book. (Report No. CR 163). Canberra, Australia: Federal Office of Road Safety.

Euro NCAP (2006). Euro NCAP announced first four-star award for pedestrian-protection. Downloaded from www.euroncap.com.

European Transport Safety Council [ETSC] (1999). Safety of pedestrians and cyclists in urban areas. Brussels, Belgium: European Transport Safety Council.

Federal Highway Administration [FHWA] (1988). Manual on uniform traffic control devices for streets and highways. Washington DC, USA: US Department of Transportation.

Fildes B, Lee S, Kenny D, & Foddy W. (1994). Survey of older road users: Behavioural and travel issues. (Report No. 57). Melbourne, Australia: Monash University Accident Research Centre.

Finch D, Kompfner P, Lockwood C, & Maycock G. (1994). Speed, speed limits and accidents. (Report No. 58). Crowthorne, UK: Transport Research Laboratory.

Gorrie C, Waite P, Sachdev P, Rodriguez M, Duflou J, & Brown J. (2004). Fatalities in older drivers and pedestrians: Neuropathological evaluation of pre-clinical dementia. Sydney, Australia: Motor Accident Authority.

Griebe P, Nilsson P, & Andersen K. (1998). Urban safety management: Overview of Danish experience. (Report No. 37). Copenhagen, Denmark: Vejdirektoratet.

Guerrier J, & Jolibois S. (1998). Give elderly pedestrians more time to cross intersections. *Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting*, Chicago, USA.

Hagenzieker M. (1996). Some aspects of the safety of elderly pedestrians and cyclists. (Report No. D-96-4). Leideschendam, the Netherlands: SWOV Institute for Road Safety Research.

Hauer E. (1988). The safety of older persons at intersections. Transportation in an aging society: Improving mobility and safety for older persons, Volume 2, Technical Papers, (pp. 194-252). Washington DC, USA: Transportation Research Board, National Research Council.

Haworth N, Ungers B, Vulcan P, & Corben B. (2001). Evaluation of a 50km/h default urban speed limit for Australia. Melbourne, Australia: National Road Transport Commission.

Holland C, & Rabbitt P. (1992). People's awareness of their age-related sensory and cognitive deficits and the implications for road safety. *Applied Cognitive Psychology*, 6, 217-231.

Hong Kong Transport Department (2003). Proposal to ban aggressive bull-bars fitted to vehicle fronts. Consultation Paper. Hong Kong Transport Department. Downloaded from http://www.info.gov.hk/td/eng/whatsnew.

Jordan P, & Jones D. (1996). Design for pedestrians. In K Ogden & S Taylor (Eds.). *Traffic Engineering and Management, (*pp 303-311).

Kent S, & Fildes B. (1997). A review of 'Walk-With-Care': An education and advocacy program for older pedestrians. (Report No. 109). Melbourne, Australia: Monash University Accident Research Centre.

Knoblauch R, Pietrucha M, & Nitzburg M. (1996). Field studies of pedestrian walking speed and start-up time. *Transportation Research Record*, 1438, 67-73.

Land Transport Safety Authority [LTSA] (2003). Bull-bars. (Fact sheet No. 22). Wellington, New Zealand: Land Transport Safety Authority.

Lange J. (2000). Bicycle and pedestrian facilities at small roundabouts in built-up areas. *VTI Konferens*, 13A(5), 23-33.

Lefler D, & Gabler H. (2004). The fatality and injury risk of light truck impacts with pedestrians in the United States. *Accident Analysis and Prevention,* 36(2), 295-304.

Li G, Braver E, & Chen L. (2003). Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. *Accident Analysis and Prevention*, 35(2), 227-235.

Macaulay J, Gunatillake T, Tziotis M, Fildes B, Corben B, & Newstead S. (2004). On-Road Evaluation of Perceptual Countermeasures. (Report No. CR 219). Canberra, Australia: Australian Transport Safety Bureau.

Maki T, Kajzer J, Mizuno K, & Sekine Y. (2003). Comparative analysis of vehicle-bicyclist and vehicle-pedestrian accidents in Japan. *Accident Analysis and Prevention*, 35(6), 927-940.

Marottoli R, & Richardson E. (1998). Confidence in, and self-rating of, driving ability among older drivers. *Accident Analysis and Prevention,* 30(3), 331-336.

Mitchell C. (2000). Some implications for road safety of an ageing population. Transport trends, (pp. 26-34). London, UK: The Stationary Office, Department of the Environment, Transport and the Regions.

Mizuno K, & Kajzer J. (1999). Compatibility problems in frontal, side, single car collisions and car-to-pedestrian accidents in Japan. *Accident Analysis and Prevention*, 31, 381-391.

National Highway Traffic Safety Administration [NHTSA] (2001). Traffic safety facts 2000: Pedestrians. (Report DOT HS 809311). Washington DC, USA: US Department of Transport.

Newstead S, & Corben B. (2001). Evaluation of the 1992-1996 Transport Accident Commission funded accident black spot treatment program in Victoria. (Report No. 182). Melbourne, Australia: Monash University Accident Research Centre.

Newstead S, & Mullan N. (1996). Evaluation of the crash effects of the changes in speed zones in Victoria during 1993-1994 (excluding 100 to 110 km/h). (Report No. 98). Melbourne, Australia: Monash University Accident Research Centre.

Nilsson G. (1984). Speed, accident rates and personal injury consequences for different road types. (VTI Rapport 277). Linköping, Sweden: Swedish National Road and Transport Research Institute.

Oberg G, Nilsson G, Velin H, Wretling P, Bentman M, Brundell-Freij K, Hyden C, & Ståhl A. (1996). Single crashes among pedestrians and cyclists. (Report No. 799A). Linköping, Sweden: Swedish National Road and Transport Research Institute.

Organisation for Economic Co-operation and Development [OECD] (2001). Ageing and transport: Mobility needs and safety issues. Paris, France: Organisation for Economic Co-operation and Development.

Öström M, & Eriksson A. (2001). Pedestrian fatalities and alcohol. *Accident Analysis and Prevention*, 33, 173-180.

Oxley J, Dewar R, & Fildes B. (2004). Safety of older pedestrians. Transportation in an Aging Society: A Decade of Experience. Technical papers and reports from a conference. Conference Proceedings 27, pp. 167-191. Washington DC, USA: Transportation Research Board.

Oxley J, Corben B, & Diamantopoulou K. (2001). Injury reduction measures in areas hazardous to pedestrians. Stage 2: Countermeasure evaluation. (Report No. 178). Melbourne, Australia: Monash University Accident Research Centre.

Oxley J, Fildes B, Ihsen E, Charlton J, & Day R. (1997). Differences in traffic judgements between young and old adult pedestrians. *Accident Analysis and Prevention*, 29(6), 839-847.

Oxley J, Ihsen E, Fildes B, & Charlton J. (2001). Age-related functional impairments and the impact on the ability to cross roads safely. *Proceedings of the Traffic Safety on Three Continents Conference*, Moscow, Russia.

Oxley J, Ihsen E, Fildes B, Charlton J, & Day R. (2005). Crossing roads safely: An experimental study of age differences in gap selection by pedestrians. *Accident Analysis and Prevention*, 37(5), 962-971.

Persaud B, Retting R, Garder P, & Lord D. (2001). Crash reductions following installation of roundabouts in the United States. *Proceedings Road Safety on Three Continents 2000.* (VTI Konferens, NO: 15A) (pp. 540-542). Linköping, Sweden: Swedish National Road and Transport Research Institute.

Reading I, Dickinson K, & Barker D. (1995). The Puffin pedestrian crossing: pedestrian-behavioural study. *Traffic Engineering and Control*, 36(9), 472-478.

Retting R, Ulmer R, & Williams A. (1999). Prevalence and characteristics of red-light running crashes in the United States. *Accident Analysis and Prevention*, 31, 687-694.

Ribbens H. (1996). Pedestrian facilities in South Africa: Research and practice. *Transportation Research Record*, 1538, 10-18.

Sheppard D, & Pattinson M. (1986). Interviews with elderly pedestrians involved in road crashes. (Report No. RR98). Crowthorne, UK: Transportation Road Research Laboratory.

Shumway-Cook A, & Woollacott M. (2000). Attentional demands and postural control: The effect of sensory context. *Journal of Gerontology A: Biological Science and Medical Science*, 55a, M10-M16.

Simms C, & O'Neill D. (2005). Sports utility vehicles and older pedestrians. *British Medical Journal*, 331, 787-788.

Smiley A. (2004). Adaptive strategies of older drivers. Transportation in an Aging Society: A Decade of Experience. Technical papers and reports from a conference. Conference Proceedings 27, pp. 36-43. Washington DC, USA: Transportation Research Board.

Ståhl A. (1991). Mobility and accessibility for elderly and disabled in Sweden. *IATSS Research*, 16(2).

Ståhl A, Brundell-Freij K, & Makri M. (1993). The adaptation of the Swedish Public Transportation System – Yesterday, today and tomorrow. An evaluation. (TFB Report No. 1993:14). Stockholm, Sweden: Swedish Transport Research Board.

Staplin L, Lococo K, Byington S, & Harkey D. (2001). Highway design handbook for older drivers and pedestrians. (Report No. FHWA-RD-01-103). Washington DC, USA: US Department of Transportation, Federal Highway Administration.

Tarawneh M. (2001). Evaluation of pedestrian speed in Jordan with investigation of some contributing factors. *Journal of Safety Research*, 32, 229-236.

United Kingdom Department for Transport (2003). Bull-bars: Consultation on options for national action. Downloaded from www.roads.dft.gov.uk/vehicle/vse6/bullbars.

Várhelyi A. (2001). Preliminary results from a large scale trial with intelligent speed adaptation in Lund, Sweden. *Proceedings of the 8th World Congress on Intelligent Transport Systems*, Sydney, Australia.

Wramborg P. (2006). A new approach to a safe and sustainable road structure and street design for urban areas. *Proceedings; Road Safety on Four Continents Conference*, Warsaw, Poland, 7-9 October.

Yanik A, & Monforton R. (1991). At fault crash patterns of older drivers. *Journal of Traffic Medicine*, 10(2), 87-92.

Yeates M. (2001). 60, 50, 40km/h – which is safest? *Australian Cyclist*, March 2001.