Older Pedestrians – Meeting their Safety and Mobility Needs

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Abstract

Crashes involving pedestrians are severe in nature and constitute a substantial proportion of serious injuries and deaths on the road. Moreover, many involve older adults. This paper discusses the contributing factors to increased crash and injury risk for older pedestrians including behavioural, vehicle and environmental factors. Walking is an essential part of many trips, however, the road environment is becoming more complex. The dominance of vehicles, high speed and traffic volumes on many roads used by pedestrians, places high demands on an older person's adaptability, whilst ageing can diminish the capacity to cope with many traffic situations. Older adults, therefore, experience many problems using the transport system, largely because it does not adequately accommodate their special needs and capabilities. Further, the design features of frontal structures of vehicles can greatly affect pedestrian injury outcome. In this paper, world 'best-practice' strategies and initiatives for managing the safe mobility of older pedestrians are identified and described, including the principles of road safety strategies in countries that are world leaders in road safety. Cost-effective initiatives are discussed such as programs that promote safe walking practices, improvements to vehicle frontal design to optimise the protective capabilities of vehicles, and innovative engineering treatments that aim to improve the 'crashworthiness' of the road transport system and be more forgiving of vulnerable road users. Several examples are described including measures to moderate vehicle speeds in high pedestrian activity areas, measures to separate or restrict vehicular and non-vehicular traffic, and measures to reduce the complexity of the road environment. Recommendations for a system-wide approach for the management of older pedestrian safe mobility are provided.

Introduction

Walking is a major mode of transport is a component of most trips and has obvious benefits for health and well-being of individuals and the environment. However, pedestrians are an extremely vulnerable road user group, largely due to their lack of protection and limited biomechanical tolerance to violent forces when impacted by a vehicle. Pedestrian crashes, therefore, are severe in nature and represent a major road safety problem world-wide. Furthermore, because of their physical frailty, older pedestrians are especially vulnerable to injuries.

There is a growing awareness within the road safety community that vulnerable road users may have their own particular needs and difficulties in using the road transport system and that this should be considered when designing and operating the system. This paper presents an overview of a comprehensive review of international literature on the safety of older pedestrians and cyclists[1] and highlights the key considerations with regard to older pedestrian crash and injury risk, and achieving fundamental improvements in the safe mobility of older pedestrians in traffic through international 'best-practice' policy, initiatives and countermeasures.

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Crash and Injury Risk

Pedestrian crashes constitute a substantial proportion of serious injuries and deaths on the road. In Australia, pedestrian fatalities make up about 15 percent of all road fatalities[2]. International figures also show that pedestrian deaths are a significant road safety problem, particularly in developing countries where they constitute up to 70 percent of all road deaths[3,4,5,6]. A substantial proportion of these crashes involve older adults, who are vulnerable because of declining function in traffic and age-related frailty, and experience many problems using the transport system. In 2003 in Australia, 86 pedestrians aged 60 years and over were killed, compared to 26 children under 16 years of age, 25 young adults between 17 and 25 years and age, 48 adults aged between 26 and 29 years and 45 adults aged between 40 and 59 years of age – this represents 37 percent of all-aged fatalities[2]. Again, similar figures are apparent world-wide[7,8,9].

Contributing Factors

Several explanations have been offered to account for the over-representation of older adults in serious injury and fatal pedestrian crashes.

Age-related functional changes and poor health status

Once involved in a crash, older road users are at extremely high risk of severe injury because of their greater susceptibility to injury (frailty) compared to younger people, and it is this factor that can explain much of the over-representation of this group. Even in moderate crashes, the elderly are in greater danger of serious injury or death compared to younger adults[7,10.11].

It is argued that older road users are at heightened risk of crash involvement because of limited functional abilities required when using the road. Much of the literature is concerned with the consequences of ageing on sensory, perceptual, cognitive and physical abilities and resulting problems coping with certain traffic situations. While there is little doubt that the onset of age-related changes affects many areas of daily living, it appears that the majority of older pedestrians use the road-transport system without injurious consequences, suggesting that, for the most part, they compensate for these changes successfully[11,12,13]. Nevertheless, there is some evidence of reduced road-crossing performance by older pedestrians, particularly the problems of selecting a safe gap in the oncoming traffic in complex traffic environments[14,15,16]. Sheppard and Pattinson's[17] survey of crash-involved older pedestrians revealed some of the difficulties crossing roads including: failure to see, or to see in time to take evasive action, the striking vehicle; an unusual manoeuvre by the striking vehicle; errors in judgements of speed of vehicle; and, a difficult place to cross. Scandinavian data indicate that more than one-third of elderly road users report health problems and find it difficult to be pedestrians[18,19,20]. Fildes et al.[21] noted similar difficulties amongst a group of older Australian pedestrians.

Vehicle design

Current design of vehicle frontal structures of both passenger cars and other larger vehicles contributes significantly to the severity of injuries sustained in a collision. Pedestrians struck by a van or four-wheel-drive with high bumpers and more blunt frontal profiles are much more likely to incur serious head, thoracic, abdominal and spinal injuries than when struck by a bonnet-type passenger car. In contrast, as passenger cars are more aerodynamically streamlined and have lower bumpers than

vans, utilities and four-wheel-drives, pedestrians struck by a car are much more likely to incur a leg injury[22,23,24].

The fitting of rigid bull-bars without deformable padding to many large vehicles is of great concern to pedestrian safety. The Pedestrian Council of Australia[25] reported that about 60 percent of four-wheel-drive vehicles in Australia and half of the utilities and vans on metropolitan roads in Australia are fitted with bull-bars, and were contributing factors in up to 20 percent of fatal pedestrian crashes on urban roads.

The road environment and traffic conditions

The safety of older pedestrians is 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 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[26]. 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[27]. Even crashes involving younger pedestrians are likely to result in serious injury at relatively low impact speeds, but older pedestrians are likely to suffer more severe injuries at lower impact speeds[28].

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[11,29,30]. 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[16,31].

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[32,33,34,35,36]. Surfaces of roads and footpaths cause problems for older pedestrians[21,35,37,38]. 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

Meeting the mobility and safety needs of older people in the future will require a comprehensive strategy, one which will encompass policy at all levels and include educational and awareness initiatives, improved vehicle frontal design, and ensuring a safe, comfortable and convenient road environment in which to walk.

The road safety philosophies of Sweden and the Netherlands incorporate innovative and effective concepts that aim to improve the safety and mobility of all road user groups. These models view safety as the prevailing consideration and argue that the road-transport system can only be safe when roads are designed and operate in a way that explicitly recognise human tolerance to violent forces and normal human error so that death and serious injuries can be prevented. This means providing environments that are forgiving of human error and designed to reduce serious injury for the most vulnerable road users using the system. Key points of the 'Vision Zero' concept relative to older pedestrians are that i) children, senior citizens and disabled persons are to be normative in the design of the road-transport system, ii) different categories of road users should be separated, allowing minimum opportunity for collision, and iii) road infrastructure improvements and overall vehicle speed reductions should be mandatory so that no user will be exposed to mechanical forces above the threshold for producing serious injury. The Dutch concept of 'Sustainable Safety' is similar and primarily aims to reduce crash risk through infrastructure design, particularly making a distinction between road functions, separating travel modes and reducing vehicle speeds in areas where vulnerable road users and vehicles mix.

Vehicle design improvements

The US National Highway Transport Safety Administration (NHTSA), the European Enhanced Vehicle-Safety Committee (EEVC) and the International Standards Organisation (ISO) have introduced pedestrian component testing for all new cars in Europe, US, Japan and Australia to provide 'optimum' pedestrian crash conditions.

Lower limb injuries, such as fractures and damage to knee ligaments can be reduced by ensuring that bumpers are placed in positions that are lower than knee level, and that heavy cross members are moved back allowing the bumper to crush at least five to 7.5 cm. Upper leg and pelvis injuries can be minimized by improvements to the vehicle bonnet edge to reduce stiffness, allow deformation of the outer skin and provide sufficient crash depth. Upper body and head injuries can be minimized by allowing a clearance space between the bonnet and the underlying engine parts (a crush depth of between 5 and 10 cm), placing of airbags near the hard structural pillars of the windscreen, or installation of a 'pyrotechnic device' that causes the bonnet to quickly rise during a crash thus creating the necessary space[39].

There is active discouragement 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[40,41,42].

Intelligent Transport System (ITS) applications also offer the potential to improve pedestrian safety including speed alerting and limiting devices, vision enhancement technologies, rear collision warning systems and 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[43,44]. Studies on the effectiveness of daytime running lights on crash rates reveal reductions in multi-vehicle daytime crashes of between 8 and 29 percent[45]. No data are available on the effect of this technology on crashes involving vulnerable road users.

Infrastructure, road design and system operation improvements

Engineering countermeasures have the potential to quickly and effectively create a safer and more 'crashworthy' travel environment for vulnerable road users. The improvements that appear to provide the most benefit for older pedestrians include: i) measures to reduce travel speeds when pedestrians are present; ii) provision of infrastructure that gives higher priority to pedestrians in critical locations; iii) simplification of traffic; and, iv) improvements to pedestrian facilities.

Speed-reduction measures – pedestrians are only safe when vehicle speeds are low, in the order of 30 to 40 km/h[45,46,47]. At these speeds, most potential collision situations can be recognized and avoided, and, if a collision does occur, damage and injury should be light to severe, but rarely fatal. Moreover, a lower speed environment can provide older pedestrians with a simpler task in which to select safe gaps in the traffic. Even small reductions in vehicle speeds result in substantial reductions in serious injury pedestrian crashes[16,27,48].

Most OECD countries have adopted general urban speed limits of 50 km/h and some permit zoning at lower speeds in residential areas and school zones because of high pedestrian and cyclist volumes. New South Wales and Victoria have introduced the 50 km/h speed limit on residential streets and recent data have shown significant crash and injury reductions road trauma in these areas[48]. Other research also shows unequivocally that crash incidence or crash severity decline whenever speed limits are reduced and increase when speed limits are raised in rural and urban areas[49,50].

Traffic-calming measures aim to reduce the number and speed of vehicles in local streets and in areas where there is high pedestrian activity. They act to make drivers more attentive to their surroundings and drive more slowly or appropriately for the surroundings. The '*woonerf*' (or home zone) concept, first developed in the Netherlands, is an excellent example of traffic-calming whereby drivers are encouraged to drive slowly by physical modifications to the roadway (such as pavement narrowing, refuge islands, alterations to the road surface, speed humps, roundabouts and gateway treatments). 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, with many reports of success[45,51].

Likewise, perceptual countermeasures (PCMs) are potentially effective treatments to reduce speeding in urban areas. PCMs unobtrusively influence the visual information on display to the driver so that they perceive that fast speed is unsafe or inappropriate. Most treatments are low-cost and do not introduce additional hazards on the roads and commonly involve painted lines or additional road surfaces to

provide the desired effect. An evaluation of two PCMs (variable height and spacing of posts on curves and peripheral edgeline painting on approaches to intersections) in urban areas revealed some speed reductions, improvements in braking and lateral placement, particularly on approaches to intersections[52].

Out-of-vehicle ITS applications have the potential to enhance speed limit compliance and these include dynamic messaging, in the form of active speed warning signs and variable message signs. In their review of active speed warning technologies, Corben, Lenné, Regan and Triggs[53] 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.

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 discourage and slow vehicular traffic and promote walking and other forms of non-motorised transport.

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[54].

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[45].

Footpaths are an integral part of the pedestrian transport network and the provision of well-maintained paved paths is associated with fewer pedestrian injuries and greater comfort[55]. Safety and mobility can be improved with appropriate design such as tactile paving, flexible tiles, ramps, high contrast surface painting and regular maintenance, particularly in winter. While the separation of pedestrians and cyclists from vehicles can overcome the risk of collision, allowing the mixing of pedestrians and cyclists does not overcome the potential problem of collisions between these two transport modes. It is also important, therefore, 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 it is suggested that the design of the traffic

area should offer sufficient time for older pedestrians to assess the traffic make an appropriate decision and perform the various tasks required in sequence[8,16,56].

Design and operation improvements can be made to intersections, particularly treatments to increase conspicuity. For example, the provision of a leading green (usually of around 3s) whereby pedestrians are able to commence crossing before vehicles can enter the intersection can increase visibility, especially to turning drivers[30,57]. The installation of conspicuous 'give way to pedestrian' signals can overcome some problems, particularly signals that are larger and brighter such as fibre optic signals[32]. In addition, pavement markings act to stimulate drivers to look for vulnerable road users. Holding lines for vehicles could be set back farther from the crosswalk[58], crosswalks can be painted with a high contrast colour[59], and footpaths could be widened and extended further into the carriageway[60].

Roundabouts are associated with major safety benefits for vehicle occupants[61,62,63]. However, the safety benefits for vulnerable road users are less clear, particularly because of inconvenience (pedestrians are often required to detour substantially to reach a crossing point) and complexity (they are potentially confusing regarding who has right-of-way, and multi-laned roundabouts allow high volumes of traffic, often travelling at relatively high speed). 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[56,64,65].

Median islands/refuges offer benefits for older pedestrians[8,16,66,67]. 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 must be located at appropriate places for pedestrians to use them – 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[11]. Secondly, 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[68,69] are clearly too fast for many slow-walking older pedestrians and there have been many calls worldwide to extend walking phases, especially in areas where there is a high concentration of older walkers[33,36,70]. A reportedly successful innovation is the installation of an 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 have been found to reduce red light violations by pedestrians[32,71,72], and reduce conflict, stress and confusion[56]. 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[73].

Behavioural and educational programs

Promotion and education of safe walking practices have long been advocated as a means of promoting a healthy lifestyle and teaching pedestrians the skills to interact with traffic safely. In recent years, there has been a major push to promote safe walking and cycling in urban areas, particularly in the European Union and several projects, the PROMISING, WALCYNG, and ADONIS projects, have identified measures that could be used to promote mobility and safety of vulnerable road users[56,74]. It appears that programs aimed at the adoption of safe walking practices that include both educational and engineering components can work well[75,76], however, more rigorous evaluations of such programs are required.

Secondly, travelling by car is a much safer form of transport than walking for older adults[11]. Initiatives that raise the awareness of the relative risks associated with modes of travel and address maintenance of safe driving practices for as long as possible are worth considering.

Conclusions and Recommendations

The safety and mobility of vulnerable road user groups is an important road safety issue and should be a priority of any transport policy. A fundamental reconsideration of the way in which the traffic and transport system functions is required, along with implementation of innovative and effective solutions to ensure that the mobility and safety of older pedestrians are met. It is also important to evaluate the effectiveness and acceptability of these strategies for use in an Australian context. Based on international 'best-practice', the following initiatives are recommended:

- Improvements to vehicle design:
    - Continued development of test procedures to assess protection capabilities of vehicles for pedestrians, particularly the design of bumpers, bonnet leading edge, bonnet and windscreen,
    - Discourage use of large, aggressive vehicles, and those with rigid bull-bars, particularly in urban areas where there is a high proportion of pedestrians,
    - Development of ITS technologies that are beneficial to pedestrians.
- Improvements to road design and operation in high pedestrian activity areas:
    - Implementation of measures to moderate vehicle speeds,
    - Introduction of measures to separate/restrict vehicular from non-vehicular traffic,
    - Introduction of measures to reduce the complexity of intersections and road lengths,
    - Improvements to crossing facilities.
- Education and public awareness:
    - Continued development and support for community awareness and educational campaigns to increase adoption of safe walking practices,
    - Continued development and support for programs that promote the continuation of safe driving for as long as possible.

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