VULNERABLE NON-MOTORIZED ROAD USERS AND SAFE SYSTEM COUNTERMEASURES

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1. A BRIEF STATEMENT OF THE ISSUE

Crashes involving vulnerable road user groups (pedestrians, bicyclists, motorcyclists and especially children and older people) represent a major road safety problem. Their crashes are frequently severe in nature and constitute a substantial proportion of all serious injuries and deaths on the road. While these groups are commonly identified as 'high risk' and most strategies stress the need to improve their safety, current road systems fail to cater adequately to their needs.

A road system can only be deemed a safe system when it responds to the needs and capabilities of all of its road users. This paper has been restricted to a consideration of those safety issues specifically affecting pedestrians and cyclists, whose problems while using the road-transport system are distinct from those of the other major vulnerable road user group, motorcyclists. Other vulnerable road users – for example, indigenous people – have also been excluded from consideration in this paper.

2. AN ASSESSMENT OF THE ROAD SAFETY ISSUE

Research clearly shows that driving or being a car passenger is far less risky than walking or cycling, based on exposure measures such as billion kilometres travelled, number of roads crossed, time spent travelling and time spent crossing roads [1 2]. It has been estimated that the risk of death to pedestrians and cyclists is between 8 and 10 times higher than car occupants [3 4 5]. This is due in part to both groups being unprotected compared to vehicle occupants, so that collisions involving even relatively low impact speeds can have severe consequences. Further, there is invariably a significant difference in mass between the striking vehicle and pedestrians and cyclists, thereby increasing the latter's vulnerability. As a final factor, young children and the elderly are especially vulnerable when struck by a vehicle, due to limited neuromuscular strength and/or resilience to trauma[6].

In Australia in 2002, pedestrians accounted for 14.5 percent of all road-related fatalities and 11.4 percent of serious injuries, while cyclists accounted for 2 percent of fatalities and 10.9 percent of serious injuries [7] .In New Zealand in the same year, 11 percent of road fatalities and 7.7 percent of serious injuries occurred to pedestrians, while cyclists represented 3.5 percent of fatalities and 5.5 percent of serious injuries[8]. International figures also show that pedestrian and bicyclist deaths are a significant road safety problem [2 9 10 11 12].

There are three main pedestrian groups that have increased crash and injury risk: children under 17 years, the elderly (60 years and older) and intoxicated pedestrians. In round terms, children account for some 20 percent and the elderly for some 30 percent of pedestrian deaths[7 8].

Holubowycz (1995) found that 38 percent of pedestrian fatalities and 29 percent of pedestrian emergency room admissions, Australia-wide, had blood alcohol content (BAC) levels at or above 0.10 percent[13]. More recently, the Transport Accident Commission (2002) reported that, of the known cases in Victoria, 35 percent of pedestrians killed in 2001 had a BAC of 0.05 percent or over and the majority of these were more than three times over the legal limit for driving (i.e., a BAC exceeding 0.15 percent) [14].

Amongst bicyclists, 41 percent of deaths in Australia involve males between the ages of 26 and 59 years[7]. However the crash patterns for cyclists differ across countries, most likely because of differences in travel patterns. Many countries for example, report high crash and injury risk for child and elderly cyclists[3 15].

In Australasia, pedestrian and bicyclist crashes are usually an urban phenomenon, with most collisions occurring on urban 50 or 60 km/h zoned roads. Child pedestrian and bicyclist crashes usually occur in local streets, close to home and while the child is unsupervised, often on the way to or from school and especially while playing after school. Pedestrian crashes involving older adults also occur in built-up areas, close to home and shops, generally on a regular shopping trip, and in complex environments such as strip shopping centres, intersections and two-way heavy and fast traffic. While most older pedestrian crashes occur as a result of a collision with a vehicle (and these are the most severe), older pedestrians are also over-represented in injury events resulting from a fall or collision with other road users on footpaths. Intoxicated pedestrians are generally struck at night and close to drinking venues, and on multi-laned roads.

Again however, there are international differences. In countries such as the Netherlands, Poland and Finland, pedestrian and bicycle traffic crashes also account for a substantial share of all traffic fatalities on rural roads[16 17 18].

(However it needs to be noted that while walking and cycling represent high-risk activities from a safety viewpoint, they are associated with benefits in other contexts: for example, physical exercise and reduced environmental pollution.)

3. A REVIEW OF THE RESEARCH

3.1 Functional performance

Whether as pedestrians or as bicyclists, young children under the age of around 12 years appear to be less competent in traffic than older children and adults. This is considered to be largely due to under-developed visual, perceptual and cognitive skills that are necessary to participate in traffic safely. In particular, very young children (under the age of 7 years) lack relevant strategies, skills and understanding of traffic and road safety. Further, they are inconsistent in their road safety behaviours, easily distracted by irrelevant stimuli, experience difficulty estimating the speed and distance of oncoming cars appropriately, poor at recognizing dangerous places or at finding safe ones, tend to focus on a single factor when deciding on a crossing place, and are less likely than older children or adults to look for traffic. Small children are further disadvantaged by their height and cannot look over the top of cars to determine if traffic is approaching[19 20 21 22].

Older people (especially from around age 75 onwards) are also at heightened risk of crash involvement as pedestrians in Australasia. The evidence suggests that age-related changes in sensory, perceptual, cognitive and physical abilities contribute to this increased risk. Older pedestrians appear to experience problems negotiating complex traffic environments, particularly in selecting a safe gap in the oncoming traffic in complex environments[23 24 25 26 27 28 29]. Data also indicate that older people report health problems and functional difficulties in being pedestrians[30 31 32]. Older pedestrians also 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.

Although older cyclists do not represent a serious road safety problem in Australasia (mainly because of low levels of cycling activity), they make up a substantial proportion of bicycle crashes in some European and Asian countries. Older cyclists appear to experience problems negotiating complex traffic situations and physically controlling a bicycle, maintaining balance and keeping a straight line[33 34 35].

Intoxicated pedestrians are at increased risk of crash involvement because they may be more likely to engage in risky behaviours, they may lack awareness of their reduced performance capability, they are slower to avoid an oncoming vehicle, more likely to walk into the path of a moving vehicle, more likely to fall asleep on or near the roadway, and their ability to judge safe gaps in the traffic (particularly judging the speed and distance of vehicles) may be reduced[36 37 38 39 40 41].

3.2 System design and operation

In Australasia, many of the problems for pedestrians and cyclists stem from the fact that the basic road design standards are based on the performance capabilities of young, fit males and rarely take into account the variability in the abilities of the range of different road users that use the system. Jurisdictions have to varying degrees amended these standards to meet other road users' needs: however it remains that for the most part, systems are unforgiving of the needs and capabilities of vulnerable road users using transport modes other than the private vehicle and/or who are young, elderly or unfit.

High vehicle speed represents a key problem for vulnerable road users, particularly in circumstances where pedestrians and cyclists are forced to mix directly with vehicles. Higher speed reduces a driver's ability to control the vehicle and manoeuvre around obstacles and other road users – as well as making the vehicle's movements less predictable to other road users, including pedestrians and cyclists. 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. Further, the probability of injury and the severity of injuries increase exponentially with increases in vehicle speed – to the power of four for fatalities, three for serious injuries and two for casualties[42]. 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 over 80 percent of pedestrians can be expected to die from an impact at 50 km/h[43].

The problems of high or inappropriate vehicle speed in areas of high pedestrian and cyclist activity are often exacerbated by the fact that the modern traffic system is designed largely from a car-use perspective and other transport modes such as walking and cycling have a low status. Where jurisdictions have responded to these problems (for example, by provision of separated bicycle paths), the overall safety impact has been modest, due to the large stretches of the road network left unaffected. There are many reports of dominant attitudes and aggressiveness by drivers, poor regard for and failure to acknowledge the rights of pedestrians and cyclists, failure to give way and negative attitudes to older pedestrians in particular[44 45 46 47 48 49].

Current design of vehicle frontal structures contributes significantly to the severity of injuries sustained by vulnerable road users. Further, with the increasing rise in popularity of large four-wheel drive and sports-utility vehicles (often fitted with rigid bull-bars), the issue of vehicle design is becoming more relevant to pedestrian and cyclist safety[50 51 52]. Pedestrians and cyclists struck by a large vehicle with higher bumpers and more blunt profiles are likely to incur serious head, thoracic, abdominal and spinal injuries. As passenger cars are more aerodynamically streamlined and have lower bumpers, pedestrians and cyclists struck by a car are more likely to incur a leg injury.

The fitting of rigid bull-bars without deformable padding is also of great concern to the safety of vulnerable road users. These devices are very stiff and concentrate crash forces in a smaller area and therefore are more likely to produce death or serious injury in a collision. Reports suggest that up to 20 percent of pedestrian deaths can be attributed to impacts with rigid bull-bars[853 54].

3.3 Effective measures to provide protection for non-motorized vulnerable road users

Meeting non-motorized vulnerable road users' particular needs and difficulties at best requires a comprehensive strategy that encompasses educational and awareness initiatives, improved infrastructure and road design and improved vehicle design. Improved design and operation of the road system, in particular, can achieve immediate cost-effective reductions in crash and injury risk to these groups of road users.

The management of urban safety in some European countries (including explicit recognition of non-motorized vulnerable road users), is predicated upon a hierarchical division of streets and roads that sets appropriate speed limits and facilities, according to road function and road user mix. In this way, a safe system is provided which allows all road users to behave safely and appropriately in each environment.

In the Netherlands for example, four types of road make up the urban road network, with each street or road having one exclusive function. There are through roads, distributor roads, access roads and residential roads and each provides varying facilities for pedestrians and cyclists. For example, urban distributor roads separate traffic directions by use of an unbroken line and usually provide a separate cycle path or cycle lane. The speed limit is set at 50 km/h, and at locations where cyclists and pedestrians can cross over is no more than 30 km/h. This reorganization of the urban road network has resulted in very large reductions in casualties –17 percent for fatalities and 22 percent for personal injury to these road users[15 55].

The '*woonerf*' (or home zone) concept, first developed in the Netherlands, and used extensively on residential roads, provides an excellent example of how shared-use streets and public spaces can achieve safe mobility for pedestrians and cyclists. In essence, this concept ensures that roads, streets and public spaces are defined not by the needs of vehicular traffic but by the needs of pedestrians and cyclists. In 'best-practice' designs, traffic-calming measures are used to form an overall design concept whereby pedestrians and cyclists have priority, while high speed through traffic is discouraged. This concept is applicable to residential areas but can also be expanded to other areas where there is high pedestrian and cyclist activity and where high speed is not necessary such as in town centres, and shopping areas. *Woonerfs* have been installed in many northern European countries, with many reports of success[9 56].

The Swedish approach to re-organizing its road network assumes that urban areas need to achieve three basic goals: accessibility, safety and a 'good' environment. As a consequence, five urban street types have been developed and defined in terms of road user mix:

(i) through traffic roads – arterial roads where vehicles are given priority. The speed limit is generally 70 km/h and reduced to 50km/h at intersections. There is minimal mix between transport modes, therefore grade separated crossings are ideally provided;

(ii) 50/30 streets – main streets where vehicles and non-motorized vulnerable road users mix. These streets are therefore designed to support a good interaction between road users, support feelings of mutual responsibility, and maintain low vehicle speeds. A maximum of speed limit of 30 km/h is set at pedestrian and cyclists crossings, otherwise it is 50 km/h. Traffic-calming treatments are introduced at crossing points to ensure lower speeds are maintained;

(iii) 30 streets – residential streets where priority is given to non-motorized vulnerable road users. No through traffic is allowed and the speed limit is set at 30 km/h. Pedestrians and cyclists can cross the streets at any location and the environment is aesthetically attractive and pleasant for interaction;

iv) walking speed streets – these are also residential streets where vehicles are required to drive at walking speed, between 5 and 10 km/h. The streets is designed entirely at the same level with no kerbs, to create the atmosphere that the street is intended for everybody; and

v) car-free areas – these are pedestrian and cyclist zones, paths and bikeways where motorized vehicles are forbidden[56] .

The Dutch and the Swedish approaches represent comprehensive ‘safe systems’ strategies. Non-motorized vulnerable road users can also be given greater protection by more specific measures – particularly, through reducing traffic speeds and/or through separating road user groups. While there are always differences between different countries’ road networks, Australia’s commitment to the Safe System approach to road safety also includes a commitment to the many of the principles underlying the Swedish and Dutch strategies.

Given the powerful relationship that exists between speed and injury risk, great emphasis has been placed on reducing speeds in areas where non-motorized vulnerable road users and vehicular traffic mix, to create environments that encourage safe walking and cycling by reducing the potential for conflicts with fast-moving traffic. Most OECD countries for example, have adopted general urban speed limits of 50 km/h, with many permitting zoning at lower speeds, for example in residential areas and school zones. In Australia, all jurisdictions have introduced the 50 km/h speed limit on residential streets and there is growing evidence that the reduced default limit has been associated with substantial safety benefits in these areas [57] [58] [59] [60] [61] [62].Other research shows unequivocally that crash incidence and crash severity decline whenever speed limits are reduced and increase when speed limits are raised in both rural and urban areas[63] [64] [65].

It remains however that pedestrians and cyclists are safe only when vehicle speeds are low, in the order of 30 to 40 km/h. At these speeds, most potential collision situations can be anticipated and avoided: if a collision does occur, injury is likely to be light to severe but rarely fatal. While the 50 km/h reduction has benefits for vulnerable (and other) road users, it remains that further reductions for some streets and roads are required.

A further strategy stresses the importance of separation of transport modes. Heavy and fast-moving traffic flows are major deterrents to walking and cycling and decrease safety, therefore, provision of vehicle-free zones is an effective way of improving safety and mobility to pedestrians and cyclists. Even partial separation in form of vehicle-restricted zones can be beneficial. These areas are used world-wide 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-motorized transport. Other methods to separate travel modes include grade-separation of crossings, provision of footpath and cycle path networks, provision of barrier fencing and guardrails and signalized crossing facilities.

There are also improvements that can be made to the design of frontal structures of vehicles to effectively provide pedestrians and cyclists with 'optimum' crash conditions and there are now pedestrian component testing for all new cars in Europe, the US, Japan and Australia. A set of component tests have been designed representing the three most important mechanisms of injury for pedestrians, namely i) lower leg against the bumper, ii) upper leg against the bonnet edge, and iii) head against the bonnet and top wing. No tests address cyclist injuries, however.

With regard to the use of large four-wheel-drive vehicles, vans and SUVs in the vehicle fleet, education should be provided for drivers and vehicle manufacturers as to the injury consequences of these vehicles to non-motorized vulnerable road users.

In addition there is active discouragement by some governments of the manufacture of rigid and aggressive bull-bars and encouragement for the design and manufacture of less aggressive bull-bars. EU Directives set out requirements for the external projections of vehicles and bans sharp edges on the exterior of vehicles and 'ornaments' (EEC, cited in UK Department for Transport, 2003). Further, the EEC welcomes governmental commitments to make all vehicles pedestrian friendly and has drafted a Directive which would amend the provisions relating to sharp edges to include hard surfaces and would ensure that only non-aggressive bull-bars were placed on the market. The Hong Kong Department of Transport (2003), too, intends to ban all aggressive bull-bars fitted to the front of all on-road vehicles[66]. Standards Australia (2003) [54], has recently released new design rules that specify that bull-bars on new vehicles will have to be low profile and contour-hugging, generally conforming to the shape of the front of the vehicle to which it is fitted.

In sum, special consideration of the needs of the most vulnerable road users (pedestrians and cyclists, and particularly children and the elderly) needs to be given in the design and operation of the road system. This means providing safe and comfortable environments through the introduction of innovative physical countermeasures, in which people can walk and cycle without the threat of serious injury. In areas of high walking and cycling, pedestrians and cyclists should have priority, vehicle speeds should be reduced to around 30 to 40 km/h and appropriate measures installed to facilitate safe interaction with traffic. These modifications to the road system should be supported by other initiatives such as education programs to promote safe walking and cycling, enforcement, and improvements to vehicle frontal design. The modifications would not only improve safety but would encourage further levels of walking and cycling in safe environments, thereby contributing motorists' greater awareness of other road users.

(For a more detailed treatment of pedestrian and cyclists, in accordance with the Safe System emphasis on safer road user behaviours, see an earlier Handbook paper[67a].)

4. POLITICAL, SOCIAL AND OTHER FACTORS ASSOCIATED WITH VULNERABLE ROAD USERS

Many road safety strategies and government policies recognize the vulnerability of road user groups such as pedestrians, cyclists, children and the elderly, and stress the need to improve their safety [9 15 67b]. However, facilities for these groups, generally, are not automatically integrated in transport planning in most countries (including Australasia). Commonly, the predominant emphasis is upon vehicular travel generally and the private car use specifically, resulting in a negative effect on the safety and mobility of vulnerable road users.

Recent philosophies, however, are beginning to recognize the importance of transport modes other than vehicle travel, particularly for travelling short distances. In particular, the Swedish 'Vision Zero' and the Dutch 'Sustainable Safety' approaches are receiving much attention world-wide as innovative and effective concepts that aim to improve the safety and mobility of **all** road user groups. A unique and driving force in Sweden's concept is that '…those who run the greatest risk of being seriously injured should be the determining factor in the design of the road system'[68]. This implies that:

i) the most vulnerable groups are to be normative in the design and operation of roads;

ii) different categories of road users should be separated, allowing minimum opportunity for collision; and

iii) infrastructure improvements and overall vehicle speed reductions should be mandatory so that no road user will be exposed to mechanical forces above the threshold for producing serious injury.

Austroads' decision to adopt a Safer Systems approach for Australasia is to be welcomed for a number of reasons, not the least being the potential impact which can be made upon vulnerable road user injuries and deaths. The extent to which this impact can be achieved however, depends upon many other factors – not the least being the extent of political and financial commitment at national and jurisdictional levels.

5. Conclusions

Meeting the mobility and safety needs of non-motorized vulnerable road users will require a comprehensive strategy which ensures a safe, comfortable and convenient road environment, allowing for the safe interaction of all road users. Engineering countermeasures in particular have the potential to quickly and effectively create a safer and more 'crashworthy' travel environment for these road user groups. The improvements likely to provide the most benefit for these groups include:

i) provision of infrastructure that gives higher priority to non-motorized vulnerable road users in critical locations than they currently have

ii) measures to reduce travel speeds of vehicles in areas of high pedestrian and cycling activity

iii) separation of travel modes where appropriate

iv) pedestrian-friendly improvements to vehicle design.

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