Pedestrians: Vulnerable Road Users Facing Increased Risk of
Death and Injury in Cities

Walking is a fundamental part of everyday travel and one of the best possible ways of getting around in cities. However, pedestrians face real risk while sharing the road with vehicles, too often resulting in injuries and deaths. In the field of road safety, risk refers to the probability of a collision occurring in terms of two dimensions: frequency and severity of the consequences (time loss, property damage, injuries, fatalities) (Haight 1986; Hauer 1982). As stated by Lassarre (2016) in Transport Planning and Traffic Safety: Making Cities, Roads, and Vehicles Safer, we live in a risky society, which implies that road users are subject to threat by moving vehicles on the road. In this context, vulnerable road users (VRU) is a term applied to those most at risk in traffic (OECD 1998).

The Institute for Road Safety Research (SWOV) suggests three criteria to distinguish VRU from other road users: the absence of a protective ‘shell’ in traffic to protect against kinetic energy (e.g. pedestrians, cyclists and, to some extent, motorcyclists); lower level of task capability (e.g. children and older adults); and lower resilience in the case of injuries (e.g. older adults and people with disabilities) (Hakkert and Braimaister 2002). Because of those criteria, the injury and death risk associated with each transport mode is unequal. Kinetic energy determines injury severity. The total kinetic energy brought to a collision is the mass times the square of the velocity of each colliding object. A small, light, slow pedestrian cannot absorb the kinetic energy of a heavy vehicle moving rapidly without sustaining severe injury.

A global status report on road safety published by the World Health Organization (WHO) in 2015 indicates that 22% of the road casualties around the globe are pedestrians (see Figure 24.1). Moreover, the proportion of pedestrian deaths compared to deaths of other road users varies between WHO regions: from 13% in South-East Asia to almost a quarter of the deaths in developed regions such as the Americas, Europe and the Western Pacific and 39% in Africa. Even if these numbers partly reflect the predominant form of mobility in those regions, the burden of pedestrian deaths and injuries represents a serious issue in population health at the regional and country levels. High-income countries have higher degrees of motorization but also substantially safer road environments, leading to substantially lower numbers of pedestrian deaths per capita compared to low-income countries. As motorization increases in low-income countries, there is the potential for an increase in all types of road user deaths.
Figure 24.1 Road traffic deaths by type of road user, by WHO region.

Cities contribute an important proportion of the burden of pedestrian fatalities and injuries in high-income countries as well as in low-income countries (WHO 2013b). This is not surprising, since cities usually concentrate the most pedestrian and traffic encounters. This means that the total number of injured or dead pedestrians is at its peak in cities, representing up to a third of traffic deaths in some American cities (Transportation for America 2011). Moreover, an Organisation for Economic Co-operation and Development (OECD) report demonstrates that between 50% and 80% of pedestrian fatalities and between 75% and almost 100% of serious and slight injuries occurred on urban roads (OECD 1998) (see Figure 24.2). Similar numbers can be found in the United States. The Dangerous by Design report revealed that more than 47,700 pedestrians were killed and more than 688,000 were injured in the United States between 2000 and 2009, and that almost three-quarters of these pedestrians were struck and killed by a vehicle in an urban setting (Transportation for America 2011). A more recent OECD report highlights better progress made in the prevention of motor vehicle occupant deaths in recent years, but less progress and sometimes an increase in road deaths for pedestrians, especially those above 65 years of age (International Transport Forum 2016). This is also true in the United States, where fatalities from car crashes dropped by 27% between 2000 and 2009, while the drop was only 14% for pedestrian fatalities (Transportation for America 2011). In low-income countries the pedestrian injury burden is high in cities in all the countries surveyed, but can be either high or low in rural areas, depending on the degree of rural motorization (Ghaffar et al. 2004; Kobusingye et al. 2001; Labinjo et al. 2009; Moshiro et al. 2005). Cities are an important focus for pedestrian and cyclist injury intervention because there is always a mix of motorized and vulnerable road users to consider. The solutions to vulnerable road user crashes in rural areas are likely quite different owing to lower densities and higher speeds, and are not considered in this chapter.

This chapter explores the issue of pedestrian injuries in cities by first taking a closer look at risk factors for pedestrians. Then it expands the discussion of pedestrian injuries in cities with three case

![Pedestrian road injuries Both sexes, All ages](image)

**Figure 24.2** Pedestrian death rates per 100,000 population are much higher in low-income countries than in high-income countries.

*Source: Institute for Health Metrics and Evaluation (2017).*
studies: the greater risk found in deprived neighbourhoods, the particular needs of senior pedestrians, and the situation in low-income countries. Finally, the chapter discusses interventions known to prevent pedestrian injuries in cities.

**Risk Factors for Pedestrian Injuries in Cities around the World**

The past decades have seen a rise in the understanding about pedestrians’ exposure to risk. Factors associated with an increased risk are present at the individual, contextual and environmental levels.

**Individual Level Risk Factors**

At the individual level, the driver selects the vehicle speed, which is the dominant common risk factor both for the occurrence of a pedestrian crash and for the risk of severe or lethal consequences. A higher driving speed means less time for the driver to see and respond to danger, and a longer stopping distance. These make a pedestrian crash more likely to occur. When a pedestrian crash occurs, the impact speed directly determines the potential for a fatal outcome, as shown in Figure 24.3. Fatality is very unlikely at impact speeds of 30 km/h (18.6 mi/h) or less, and is almost a certainty at the 80 km/h (49.7 mi/h) speed that can be attained on many urban arterial roads (WHO 2015).

The pedestrian must succeed in the complex task of crossing a street, which requires actions that several sub-groups of the population cannot achieve safely. Since more than half of pedestrian crashes are known to be at intersections, making those tasks easier to perform is potentially a good way to reduce risk for everyone. Table 24.1 illustrates crossing tasks with the underlying capacities needed to accomplish them. For example, child (under 12) and senior (over 65) pedestrians are the ones who face the most challenge within those actions because of both their physical condition (smaller height,
slow walking speed) and their cognitive abilities. For more details, see, among others, Tournier et al. (2016) for seniors and Stevenson et al. (2015) for children.

**Social, Political and Legislative Context**

What is deemed the ‘contextual level’ includes actions undertaken at all levels of government, from the local to the global: efforts toward better legislation to protect pedestrians through enforcement (speed limits, drinking and driving ban, etc.), vehicle design standards or trauma care (urgent medical treatment system in place) have the potential to reduce the pedestrian death risk. Assuring mobility but emphasizing intrinsically safer modes, for example, rail-based transportation, also reduces the number of traffic crashes and road deaths. A policy approach that explicitly minimizes private vehicle trips in cities has many potential societal benefits including health and safety. Other social context variables such as deprivation have an impact of road safety, as will be detailed further in our first case study below.

**Built Environment Level Risk Factors**

Beyond these individual and contextual characteristics, streets and intersections have also been studied for their associations with pedestrian crashes. Characteristics such as heavier traffic or the presence of arterial roads are known to increase collision rates in an urban context (Dumbaugh and Li 2011; Maillot et al. 2017; Morency et al. 2011). On the contrary, signalized intersections (traffic lights) are known to decrease risk for children and adults (Rifaat et al. 2011; Rothman, Buliung et al. 2014). Similarly, visibility, for both pedestrians and drivers, is crucial for avoiding collisions at intersections. Accordingly, parking bans (or absence of parked vehicles) and traffic calming devices such as kerb extensions have been put forward as measures to reduce risk at intersections, which gave mixed results in terms of crash reduction. Most research in this area again comes from high-income countries.

**Case Studies**

The next three case studies make the point that person, place and context must be understood and taken into account when considering the problem of pedestrian injuries in cities. Although there

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**Table 24.1 Actions required to cross a street**

<table>
<thead>
<tr>
<th>Task to cross safely</th>
<th>Actions to perform</th>
<th>Underlying challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selecting a location to cross.</td>
<td>Go to the nearest marked crosswalk (if any).</td>
<td>Being able to navigate in the city and walk for a long time.</td>
</tr>
<tr>
<td>Exploring the visual environment.</td>
<td>Move head to right and left to examine traffic and gather other information.</td>
<td>Seeing and being seen.</td>
</tr>
<tr>
<td>Choosing a time gap for crossing.</td>
<td>Decide if the time available between two vehicles exceeds the time needed to cross.</td>
<td>Seeing and hearing traffic (and speed indicators) and walking fast enough.</td>
</tr>
<tr>
<td>Start-up time and crossing time.</td>
<td>Reduce the time between the decision to cross and the first step on the street.</td>
<td>Not hesitating; going down the sidewalk (if any).</td>
</tr>
<tr>
<td>Calibration of walking speed to traffic perception.</td>
<td>Get visual feedback from vehicles and adapt walking speed.</td>
<td>Being able to change walking speed quickly, and being able to estimate approaching vehicle speed.</td>
</tr>
</tbody>
</table>

*Source: Adapted from Tournier et al. (2016).*
are some global approaches that apply in all cities and all neighbourhoods (e.g. speed reduction and transportation modal shifts), it is important to understand the particulars of a city, a neighbourhood or a population group in order to fully achieve reductions in road injuries and deaths. First, we discuss the relationship between social deprivation and pedestrian injury risk using children as the example. Second, we discuss the fact that built environment features (specifically intersection crossing controls) may not match the needs of all road users, using the example of seniors. Finally, we employ the case of India to highlight the ways in which cities in low-income countries (where the injury burden is higher) may be the same or may differ from those in high-income countries (where more of the prevention literature is currently published).

**Case Study One: Child Pedestrians at Greater Risk in a Deprived Neighbourhood**

Globally, pedestrians represent the largest category of children involved in road crashes: up to 40% of children injured in low- and middle-income countries are pedestrians (Peden 2009). The decline in child pedestrian death and non-fatal injury rates has recently stalled or reversed in several high-income countries, including the United States, where as many as 75% of child pedestrian injuries occur in urban areas (Austin et al. 1997), and Sweden, surprisingly, since it has been the most successful country in historical road safety achievement (International Transport Forum 2016). The last decades of advance in geographic information science and methods permit a whole new range of study in road safety, namely those relating the built and social environment to crash location (Richards et al. 1999).

A good example of such studies is those examining the close relationship between area-based deprivation and child pedestrian injuries, which is the focus of much attention since the 1980s (among others, see: Graham et al. 2013; Laflamme and Diderichsen 2000; Oliver and Kohlen 2009; Rivara and Barer 1985; Rothman et al. 2017). In those studies, it is mostly the relative deprivation concept that is studied, namely where an area’s living conditions are below those of the majority in a given population (Townsend 1987). Usually, deprivation indices bring together a number of variables, such as unemployment rate, proportion of single-parent families or level of education to capture the complex socio-economic portrait of a given area, and these indices can then be compared to health outcomes, namely here child pedestrian crashes.

The results of these studies, mostly undertaken in developed countries, highlight an inequity in child pedestrian risk and rates according to their socio-economic status at either the family or the neighbourhood level (Hewson 2004). This overrepresentation of low-income injured child pedestrians is explained by both individual and environmental variables. At the individual level, many authors found that children from low-income families walk more often (lower car ownership rates in these families) and for longer distances, and are less supervised than other children when on the roads (Macpherson et al. 1998; Roberts et al. 1997; Steinbach et al. 2014). At the neighbourhood level, it is the greater presence of traffic and major road infrastructure that increases the risk in deprived neighbourhoods. In addition to walking more, children living in low-income neighbourhoods have to cross busier streets more often than in other neighbourhoods, making it a significant variable in the road risk (Green et al. 2011; Mueller et al. 1990).

For example, in Montreal, Canada, work by Morency et al. (2011) demonstrated that the mean number of injured child pedestrians per 100 intersections was 6.4 times higher in poor versus rich neighbourhoods. This ratio went down to 3.7 for cyclists and to 3 for car passengers. Figure 24.4 illustrates this co-concentration of crash sites and deprivation measured by the proportion of low-income dwellings per census tract for the Island of Montreal, Canada. Despite the fact that these are crash locations not taking into account any exposure, we can clearly see
a pocket of co-occurrence along a north-east/south-west axis, going through the old boroughs built on a grid-like street network urban fabric.

**Case Study Two: Senior Pedestrians and Slow Walking Speed**

The need for active living as we age is a crucial part of ‘global age-friendly cities’ (WHO 2007). While walking is a very good and easy way of staying active, senior pedestrians face risk each time they walk around their neighbourhood. As a consequence, they are often overrepresented in pedestrian crashes: in the US and Germany, fatality and severe injury rates are two times higher for pedestrians over 65 years old, and trends are going up (Buehler and Pucher 2016). Senior pedestrians are also typically more severely injured in road crashes and stay longer in hospital (three to five times more than injured pedestrians aged 15 to 64 years) (Abou-Raya and Elmeguid 2009). But the impact of traffic and crash risk on seniors’ perception and self-regulation is just as concerning, since it has consequences for the social life and autonomy of elders: going out and about to run errands and meet with friends and family is also part of healthy ageing.

The overrepresentation of seniors in pedestrian casualties is related to their pre-existing health conditions, but also to their difficulties in carrying out tasks involved while walking, including street
crossing. Recent work in behavioural and environmental psychology permits the identification of risky situations and potential solutions to help stop the upward trends in senior pedestrian casualties. We present two examples of this work here. Naturalistic observational studies and an innovative simulator protocol have found complementary applicable results about older adult behaviours while crossing a street. For example, a Canadian team studied older adult pedestrians using naturalistic data collection. Pairs of observers recorded crossing behaviour characteristics at different crossing sites in urban and suburban settings. Variables such as walking speed, vehicle–pedestrian interaction, and pedestrians finishing crossing on a red light were recorded and further analysed. Finishing crossing on red was related to both individual context, i.e. physical mobility restrictions typical of older age (use of a cane, slow speed), and crossing environment. Of all the variables in the regression models, the presence of cycling infrastructure (at the crossing’s intersection) increases by six times the odds of finishing a crossing on red. Figure 24.5 illustrates an example of a street intersection where pedestrians were observed crossing. We can imagine that this type of street configuration requires additional cognitive effort, as bicycles arrive in a different lane and at different speeds from cars, and from two directions: a situation not easy to manage for seniors (Lachapelle and Cloutier 2017).

Another example lies in the work of a research team at the Institut français des sciences et technologies des transports, de l’aménagement et des réseaux (IFSTTAR) that is working with a unique simulator where pedestrians can cross a 7-meter-wide street in virtual reality. As the pedestrians walk along within the simulator, the street environment is projected on ten different screens in real time, making it possible to study pedestrians’ decision-making processes while crossing (see Figure 24.6).

The research projects using this simulator compared how senior pedestrians of different ages and younger adults cross the street. In the first case, the younger old (aged between 60 and 72 years) and the older old (aged between 73 and 92 years) both experienced a higher mean percentage of collision than the younger adults (aged between 18 and 25 years) while performing a street-crossing task several times (n=42) in the simulator (Dommes et al. 2014). Moreover, when traffic characteristics were varied across street-crossing trials, all the characteristics were significantly different for older pedestrians: a higher percentage of collisions occurred in two-way traffic situations (compared to one-way traffic) when vehicles approached from the far lane (compared to the near one) and when speed was higher (60 km/h [37.3 mi/h] compared to 40 km/h [24.9 mi/h]).

Figure 24.5 Example of crossing where older pedestrians have to manage a bike lane in Montreal, Canada. Source: Google Street View, June 2017.
Simulator-based training did not improve street-crossing safety for elderly pedestrians in the long run (Dommes and Cavallo 2012). In fact, differences in behaviours between the trained and the control groups were apparent immediately after the training sessions in favour of the trained pedestrians, but those differences were no longer observed six months after training. As the authors said, ‘This finding may reflect age-related perceptual and cognitive difficulties that cannot be remedied by a behavioural or educational training method’ (Dommes and Cavallo 2012). Such results highlight the need for roads that are designed for everyone, and a built environment adapted to the expected range of behaviours and capabilities of those who use it, young and old.

**Case Study Three: Pedestrians in Low-Income Countries**

India is a rapidly developing low-income country with 45 cities of a million or more people as of the 2011 census. Each Indian city has a unique geography and pedestrian environment. Mohan et al. (2009) reported on pedestrian fatalities in two representative cities—Mumbai, a megacity of over 12 million people, and Kota, a small city of 700,000 people. In both cities, pedestrians led all other road users in terms of numbers of deaths per year. In Kota the majority of pedestrian fatalities were young adults, in Mumbai older adults (45 and up) predominated, and in both cities fatalities among seniors were far higher than the population proportion. Most pedestrian fatalities occurred at mid-block locations rather than at junctions. Buses, trucks and commercial vehicles were overrepresented as striking vehicles. The authors suggested that the mid-block location and the preponderance of
large commercial vehicles represent a traffic environment where there may be no sidewalk, and no road space at all which is exclusively for pedestrians. The massive vehicles which share the road edge with the walking public are large enough to cause fatal injury even at low speed. Rapid motorization, and the wide use of motorized two-wheelers in Indian cities, is creating an increase in risk for pedestrians (Garg and Hyder 2006). Fatalities are increasing every year, and projections suggest pedestrian fatalities may continue to rise until 2030 to 2040 (Mohan et al. 2009).

Mohan et al. (2009) acknowledged that little research on pedestrian safety interventions has been done in Indian cities, but they were able to combine their knowledge of the local traffic circumstances and the fatality data with the mostly European literature and come up with a set of recommended interventions. They broke these into exposure, risk and consequences categories. Reducing the exposure could be accomplished by separating pedestrians from vehicles in space, for instance by providing sidewalks, paths or pavements alongside all urban roads. Reducing the risk of a collision could be done by limiting the speed of vehicles, installing roundabouts instead of four-way crossings, and restricting free left turns. Reducing the consequences of a collision can be done by making vehicles more pedestrian friendly. This would include, for example, side guards on trucks to prevent pedestrians from getting below the wheels, or requiring pedestrian friendly front ends for the many new small light cars now appearing on Indian roads.

Recognizing that collisions will continue to occur for decades in the Indian subcontinent, it is important to emphasize the role of improving access to trauma care in the region. A paper by Noordin et al. reports on the impressive results of implementing structured trauma care training within a large teaching hospital in Karachi, a megacity in the region. Comparing the five years before to the five years after introduction of structured training, the authors noted a reduction in hospital trauma mortality from 9.7% to 5.7% (Noordin et al. 2011). Clearly the augmentation of the health system is a necessary part of a city’s response to road traffic injury. This includes emergency medical and ambulance services, hospital trauma care, access to essential surgical services for the population, and rehabilitation and re-integration into the community for trauma victims.

A balanced approach for growing global cities is to fund both crash prevention and trauma care. Crash prevention can be accomplished by using local data to inform the selection of evidence based policy and built environment interventions. Given the substantial differences between cities in low-income countries and those in high-income countries, there is a strong case to be made for rigorous evaluation of locally appropriate interventions in order to turn the tide of injuries driven by rapid urbanization and rapid motorization.

**Pedestrian Injuries in Cities: Interventions and Their Effectiveness**

Effective interventions exist to prevent road traffic injuries and deaths, including pedestrian injuries. Given the nature of the problem, multiple interventions working together are required using the Haddon matrix and WHO frameworks below.

**The Haddon Matrix Explained**

A traditional construct for considering the potential to reduce the burden of injury is the Haddon matrix (Haddon 1968). Haddon divided the opportunities for prevention into three time periods—pre-crash, during the crash and after the crash. He also considered the three components of a crash—the host (i.e. the injured victim), the agent (i.e. the striking vehicle) and the environment in which they interact (including the physical road environment, but also the regulatory, social,
legal and health care environment). Combining three time periods with three components yields a nine-cell matrix. An example, regarding a child pedestrian crash, is given in Table 24.2. This example of a Haddon matrix lists some interventions that can prevent child pedestrian injuries and deaths. Interventions are organized according to whether they influence the host, agent or environment in which the crash occurs, as well as according to when they occur—before, during or after the crash.

Thinking about road crashes systematically using a Haddon matrix is informative in many ways. The time of the crash is the time of kinetic energy interchange. Much of the success in road safety in past decades has been in kinetic energy management at the time of the crash through improved in-vehicle systems (seat belts, airbags and vehicle safety cages). Vulnerable road users, by definition, benefit less from interventions aimed at crashworthiness. A dramatic exception is the substantial benefit a helmet confers to a cyclist or motorcyclist. Beyond helmets, the interventions for vulnerable road users need to focus on the pre-crash phase and make crashes less likely to happen in the first place.

Focusing on the pre-crash phase means separating vehicles in space and in time from pedestrians and cyclists. In some cities this means starting with simple things like sidewalks for pedestrians if they currently share the road with vehicles (see the India case study), whereas, in other cities with such infrastructure already, more sophisticated means of separation of routes may be considered. In very busy areas the safest designs are those which completely separate pedestrians from cars, for example grade separated roundabouts where pedestrians stay at the level and motor vehicles circulate below or above grade. These designs are expensive and not suitable in all settings.

Where pedestrians and vehicles do need to interact, it is often safer to permit pedestrian crossing trajectories only at times when vehicles cannot enter an intersection, and vehicle crossing and turning trajectories only when pedestrians are not allowed. Different strategies are needed for neighbourhood roads versus arterial roads. Some ‘afterthought’ means of separating vehicles from pedestrians, including overpasses, have been shown to be ineffective in different low- and middle-income countries (Brazil, Uganda) for the same reason (Ameratunga et al. 2006). The pedestrian overpass was not used by people who felt vulnerable to street crime and who did not like to climb stairs, so an increase in risk due to informal crossing of now faster traffic resulted.

<table>
<thead>
<tr>
<th>Table 24.2 Haddon matrix for child pedestrian injuries and deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Host (child pedestrian)</strong></td>
</tr>
<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Crash</strong></td>
</tr>
</tbody>
</table>

Source: Adapted from Haddon (1968).
Controlling vehicle speed appears in many cells in the matrix for good reasons. A driver requires a dramatically increased reaction plus braking distance if speeding (see Figure 24.7), and is therefore more likely to crash into a pedestrian who enters the road at an expected or unexpected location. An environment that is built to slow cars at crossing locations (roundabouts, raised pedestrian crosswalks) or in neighbourhoods (traffic calming) creates less possibility for driver error, and an easier traffic stream for pedestrians to judge and negotiate. Finally, in the case of an impact, the vehicle speed is the most important determinant of severe or fatal injury (remembering Figure 24.3).

The fact that interventions exist in every cell of Table 24.2 is an important observation. First, it implies the multidisciplinary and co-ordinated approach necessary in order to achieve safe cities for pedestrians. Second, it promises the benefit of synergy. If an intervention in a particular cell has a modest effect—say reduces the risk of a fatal outcome by 20%—then it can still contribute to an impressive reduction in overall harm. Suppose we implement four measures in four different cells, each with a 20% risk reduction. The risk of a harmful outcome is then \((0.8 \times 0.8 \times 0.8 \times 0.8) = 0.41\) of what it was previously. In other words six out of ten harmful outcomes can be prevented by implementing these four seemingly modest interventions together. Recognizing that speed control affects both pre-crash probabilities and during-crash consequences again re-emphasizes the importance of effective speed control for all crash types and all road users, but especially for pedestrians in the urban setting.

Awareness, education, and advertising campaigns are often an initial response to a road safety problem. Sometimes they are the only response. Publicity and education as the only response to road safety are inappropriate and counterproductive. Education alone has never been proven effective in reducing pedestrian injuries. A systematic review of multiple randomized trials of road crossing training for children (Duperrex et al. 2002) showed little permanent effect on road crossing behaviour and no effect on injury. On the positive side, it may be difficult to implement physical or environmental measures without the participation and understanding of the public. For example, the major benefits of seat belt use can only be gained with ongoing enforcement campaigns until buckling up becomes the culture (Williams and Wells 2004). Over-reliance on publicity and education alone, however, risks directing resources ineffectively and therefore away from effective solutions.
World Health Organization Framework

The WHO estimates that half of road deaths could be prevented by the full implementation of interventions which already exist and are already known to be effective (WHO 2015). As said before, almost all of the published research on prevention of road injuries comes from high-income countries, whereas the majority of deaths occur in low- and middle-income countries. Interventions to prevent pedestrian and cyclist injuries will include changes to city planning and the physical traffic environment, and will require context-specific study and adaptation to make them work in low- and middle-income countries.

The intervention framework promoted by the WHO in the 2013 global road safety status report is well aligned with Vision Zero thinking (WHO 2013a) (see below). The WHO suggests interventions including:

Managing risk exposure through policy
- reducing motor vehicle traffic;
- encouraging use of safer modes of travel;
- minimizing exposure to high-risk scenarios.

Shaping the road network
- safety awareness in planning road networks;
- incorporating safety features in road design;
- remedial action at high-risk crash sites.

Crash protective vehicles
- improving the visibility of vehicles;
- crash-protective vehicle design;
- intelligent systems for road vehicles.

Setting and securing compliance with key road safety rules
- setting and enforcing speed limits;
- setting and enforcing alcohol impairment laws;
- medicinal and recreational drug use;
- commercial drivers’ hours of work regulations;
- cameras at junctions with traffic lights;
- setting and enforcing seat belt/restraint use;
- setting and enforcing crash helmet use;
- education, information and publicity.

Post-crash care
- chain of help for people injured.

The WHO list of priorities begins with a policy and system approach that would promote a reduced volume and speed of traffic on a better-designed and safer road network. Both of these are important pre-crash interventions that will stop crashes from happening in the first place. It considers both crashworthiness and post-crash care. The interventions fit into many cells in the Haddon matrix. The list envisions a system that allows for lapses in human behaviour but enforces against serious lapses such as drink or drug impaired driving, or speeding. The need for education and awareness campaigns is acknowledged, but these are supportive rather than primary interventions. Inspecting this list of priorities with the lessons learned from considering the Haddon matrix suggests that a
local adaptation and implementation of this very list will lead to successful intervention in many cities worldwide. Davies and Roberts (2014) suggested that initiatives such as the Global Road Safety Partnership, which is highly funded by the motor industry, tend to overemphasize education and publicity campaigns rather than an evidence-based scientific and system-wide approach in their interventions, documents and tools. As these authors stated, ‘Care must be exercised to ensure that the preferences of public private partnerships do not dominate the policy arena’ when it comes to road safety interventions.

**Evidence of Effectiveness of Pedestrian Interventions**

A systematic review of the effectiveness of individual road design interventions found that pedestrian crashes can be decreased by 75% in a specific location with the appropriate road re-design (Retting, Ferguson, and Hakkert 2003). Highly effective interventions included single-lane roundabouts, sidewalks, exclusive pedestrian light phasing, pedestrian refuge islands, and increased intensity of roadway lighting. A meta-analysis of area-wide traffic calming interventions found a reduction of 15% overall in pedestrian collisions, including a reduction of 25% in collisions on residential streets (Elvik 2001). A systematic review of the effectiveness of red-light cameras found these effective in reducing pedestrian injuries by 25% to 30% (Retting, Ferguson, and McCartt 2003). All of the syntheses note methodological and statistical problems in the underlying literature, emphasizing the need for ongoing and carefully planned evaluation. Educational interventions have also been studied using stronger designs including randomized trials. As said earlier, a systematic review of randomized trials of teaching pedestrian safety to children found little if any effect on road crossing behaviour at the six-month follow-up, and no evidence of reduction of injuries (Duperrex et al. 2002).

Effectiveness of interventions needs to be measured across multiple outcomes, not just crash reduction. A built environment that promotes active transportation over motorized forms yields direct health benefits. In the strongest evidence to date, a cohort study in Scotland followed 250,000 commuters prospectively for five years and found a 40% reduction in all-cause mortality for those who commuted by bicycle and 25% reductions in cardiovascular mortality for the larger group whose commute included walking (Celis-Morales et al. 2017). Research and public policy needs to be based on the association between built environment, active transportation and safety. At present the majority of the relevant research considers only two of these items at a time, ignoring the third (Rothman, Macarthur et al. 2014).

The evidence base supports built environment interventions of whatever sort where locally appropriate, suggests avoiding relying on educational interventions, and also suggests evaluation of interventions as they are implemented in new settings. The role of education is to generate public support and compliance with more effective built environment interventions, but not to stand alone as a solution.

**Vision Zero**

Finally, *Vision Zero* provides a modern paradigm for thinking about road safety. The idea is that the transportation system can be designed to eliminate fatalities and serious injuries. This requires system-wide thinking and puts people and their safety at the centre. The system needs to be designed to be forgiving of lapses in human performance. *Vision Zero* policies were first implemented in northern European countries, where they have resulted in impressive ongoing reductions in road fatalities including pedestrians, cyclists and other vulnerable road users (Tingvall and Haworth 1999). More recently *Vision Zero* policies are being introduced worldwide, often at the level of cities or states, including those in North America and also among low- and middle-income countries. Attaining a *Vision Zero* requires the use of local data to inform the selection and implementation of evidence based interventions.
Applying Vision Zero thinking in different urban environments around the globe requires understanding what is local and what is universal. Each city has an inherent urban form determined by physical geography, population, demography, history and culture. Aspects of urban form can only be changed gradually, if at all, and cannot be solely determined by the requirements of road safety. Design of roadways themselves is more amenable to change, as is the provision of safer means of mobility than private vehicles. Regulations regarding road use and their enforcement are most amenable to change. Local data on the locations and characteristics of vulnerable road user crashes are the starting point for a successful Vision Zero implementation. Selection and prioritization of interventions are based on local injury data, best evidence from other settings, and a co-ordinated approach to implementation across all the disciplines and stakeholders involved (Johansson 2009).

Vision Zero is a programmatic and ongoing approach to attaining a safe transportation environment. At present, almost 1.5 million people per year are dying in traffic worldwide. Vulnerable road users in low- and middle-income countries are at highest risk. Judicious built environment design interventions applied in the rapidly growing and changing cities in low- and middle-income countries holds the greatest potential to reduce these deaths and injuries. By promoting safe walking and cycling, we also expect to gain substantial benefits for human health through preventing the cancers and cardiovascular disease associated with inactivity. We further expect that safe, active transportation will contribute to the environmental sustainability of megacities.

Conclusion

Pedestrian injuries are a complex problem, but an entirely anthropogenic problem. We advocate looking for solutions in the built and social urban environment. The transportation system needs to emphasize safe, efficient movement of people over the primacy of moving private automobiles. No great world city is easy to drive through, but all of them can aspire to be easy and pleasant to walk through. City planning taking into consideration the needs of all road users, of all ages and backgrounds, is going to result in built environments that are safer for pedestrians. This is much more likely to prevent injuries than the previous focus on the behaviour of pedestrians themselves, which results in expensive campaigns that are at best ineffective and at worst victim blaming and counterproductive. The role of the driver is underemphasized, such that we must understand that the speed of travel of private vehicles is a primary determinant of crash occurrence, injury severity and fatality risk. The most effective ways of controlling driver speed are through traffic calming approaches, which accord road space to vulnerable road users but are also consistent with a safe and steady flow of motor vehicles. There is no city context in which we have all the answers to pedestrian injury risk. However, implementing what we know today can prevent half of road deaths, and an integrated Vision Zero approach to road safety within cities will create new proven local solutions to tackle the remainder.

References


