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PEDESTRIAN SAFETY

A road safety manual for decision-makers and practitioners

Second edition

GOOD PRACTICE

PEDESTRIAN SAFETY

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Pedestrian safety: a road safety manual for decision-makers and practitioners, second edition

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Contents

Preface

Road traffic injuries are a major public health problem and a leading cause of death and injury around the world. Each year nearly 1.3 million people die and millions more are injured or disabled as a result of road crashes, mostly in low- and middle-income countries (LMICs). As well as creating enormous social costs for individuals, families and communities, road traffic injuries place a heavy burden on health services and economies. The cost to countries, many of which already struggle with economic development, may be as much as 5% of their gross national product. As motorization increases, preventing road traffic crashes and the injuries they inflict will become an increasing social and economic challenge, particularly in LMICs. If present trends continue, road traffic injuries will increase dramatically in most parts of the world over the next two decades, with the greatest impact falling on the most vulnerable citizens.

Appropriate and targeted action is urgently needed. The *World report on road traffic injury prevention*, launched jointly by the World Health Organization (WHO) and the World Bank in 2004, identified improvements in road safety management and specific actions that have led to dramatic decreases in road traffic deaths and injuries in countries that have implemented them. Addressing the safety of powered two- and three-wheelers (PTWs), the report showed, has saved thousands of lives. The introduction of speed limits, the creation of safer infrastructure, the enforcement of limits on blood alcohol concentration (BAC) while driving, and improvements in vehicle safety are all interventions that have been tested and repeatedly shown to be effective.

The international community must continue to take the lead to encourage good practice in road safety management and the implementation of the interventions identified above in other countries, in ways that are culturally appropriate. To speed up such efforts, the United Nations General Assembly has passed several resolutions urging that greater attention and resources be directed towards the global road safety crisis. These resolutions stress the importance of international collaboration in the field of road safety.

These resolutions also reaffirm the commitment of the United Nations to this issue, encouraging Member States to implement the recommendations of the *World report on road traffic injury prevention* and commending collaborative road safety initiatives taken to date. They encourage Member States to focus on addressing key risk factors and to establish lead agencies and coordination mechanisms for road safety. These were further encouraged through the Moscow Declaration (2009), Brasilia Declaration (2015) and the Stockholm Declaration (2020).

To contribute to the implementation of these resolutions, WHO, the Global Road Safety Partnership (GRSP), the FIA Foundation and the World Bank have collaborated to produce a series of manuals aimed at policy-makers and practitioners. This manual on pedestrian safety is one of them. Initially published in 2013, it has been updated to include new evidence and case studies. These manuals provide guidance to countries wishing to improve road safety organization and to implement the specific road safety interventions outlined in the *World report on road traffic injury prevention*.

The manuals propose cost-effective solutions that can save many lives and reduce the shocking burden of road traffic crashes around the world. We encourage all to use these manuals.

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Abbreviations

ABS	antilock brake system
AEB	autonomous emergency braking
BAC	blood alcohol concentration
GRSP	Global Road Safety Partnership
LMICs	low- and middle-income countries
M&E	monitoring and evaluation
PTWs	powered two- and three-wheelers
SDGs	Sustainable Development Goals
SUV	sport utility vehicle
WHO	World Health Organization
WSB	walking school bus
4WD	four-wheel drive

Executive summary

Globally, road traffic crashes kill approximately 1.3 million people every year – more than two every minute – with nine in ten deaths occurring in LMICs *(1).* Globally, road traffic crashes are the leading cause of death among children and young people aged 5–29 *(1).*

Walking brings health, transport and environmental benefits, but roads remain unsafe for pedestrians all over the world. Pedestrians account for nearly a quarter of all deaths from crashes and pedestrian deaths are rising at nearly twice the rate of all other road traffic fatalities.

Pedestrian collisions, like all road traffic crashes, should never be accepted as inevitable because they are predictable and preventable. Key risk factors for pedestrian injuries include a lack of safe infrastructure, vehicle speed, alcohol use by drivers and pedestrians and the inadequate visibility of pedestrians.

It is crucial that all relevant authorities and bodies put the laws, frameworks and actions in place to reduce deaths and injuries involving pedestrians. Improvements to the road environment and behavioural modification measures through legislation, enforcement and education can improve pedestrian safety.

This revised pedestrian safety manual supports the development and implementation of comprehensive measures to improve pedestrian safety. It offers new case studies, data and guidance for policy-makers to help reduce pedestrian deaths.

The manual is applicable worldwide, but targets decision-makers and practitioners in developing countries. It offers key evidenced-based interventions, including on speed management, improvements to the road environment and behavioural modification measures. The steps outlined for conducting a situational assessment aim to help prioritize interventions, prepare a related plan of action and help implement and evaluate pedestrian safety measures.

In the 10 years since the first edition of this manual, the global landscape has changed significantly. With the adoption of the United Nations Decade of Action for Global Road Safety 2021–2030 and the subsequent Political Declaration adopted by the United Nations General Assembly in July 2022, countries are adopting the Safe System approach, which recognizes that road transport is a complex system with interconnecting elements that all affect each other.

A Safe System can only be achieved if safety becomes a fully integrated element in how we organize, design and build out our mobility systems. It requires looking at how mobility systems are designed and organized, how they operate and how people, vehicles and infrastructure all affect the decisions made by all users of the system, especially the most vulnerable.

Introduction

Why were these manuals developed?

Following publication of the *World report on road traffic injury prevention* in 2004, WHO, the World Bank, FIA Foundation and Global Road Safety Partnership (GRSP) produced a series of good practice manuals providing implementation guidance on interventions to address specific risk factors in road safety. The topics covered in the initial series of manuals were: helmets (2006), drinking and driving (2007), speed management (2008), seat-belts and child restraints (2009), data systems (2010), pedestrian safety (2013), road safety legislation (2013), powered two- and three-wheeler safety (2017) and bicyclist safety (2020). In addition, WHO produced a road safety technical package, Save LIVES (2017), which provides 22 evidence-based interventions related to speed management, leadership, infrastructure, vehicles, enforcement and post-crash care.

Why are these manuals being revised?

Since the series of manuals was first published, the scientific evidence base relating to various risk factors and the effectiveness of interventions has grown. Research has refined our knowledge about specific risk factors, such as distracted driving, and vehicle-impact speed and risk of death for pedestrians. It has also identified emerging road safety issues such as e-bikes, drugs other than alcohol, fleet safety, urban mobility, micro mobility options, air and noise pollution, public transport and technological advances, thereby generating necessary policy responses.

Since the original series of manuals were published, new standards have been set (such as a tropical helmet standard and an anti-braking control standard for motorcycles) and new and existing interventions have been implemented and evaluated, increasingly in LMICs.

As a result of these developments, the good practice manuals required revision so that they can continue to be key references for road safety policy implementation and research. This is particularly important given the emphasis placed on road safety within the framework of the 2030 Agenda for Sustainable Development and because of the global impetus to reduce road deaths and injuries resulting from the declaration of the two United Nations Decades of Action for Road Safety (2011–2020 and 2021–2030). The manuals have been revised to reflect these developments as they continue to be valuable resources providing evidence-based and cost-effective solutions to save lives and reduce injuries. An extensive literature review has informed the revision and updating of all the manuals, and additional information has been collated to allow more contemporary case studies to be showcased. In addition, the need to broaden the topics covered in the manuals to include aspects such as qualitative research methods and participatory approaches to designing and evaluating interventions was identified. An emphasis on shifting traditional thinking away from blaming road users towards more contemporary frameworks, such as the Safe System approach, is key in the revised manuals.

A review of the evidence on risk factors and interventions was conducted for information for revision of this manual. The review utilized text mining techniques to gather evidence on risk factors and outcomes of interventions. This technique creates computational algorithms for reading and extracting texts from a large volume of information in a short period of time. The review was limited to January 2008 to December 2019, with the understanding that the previous manual had drawn on the evidence that existed before January 2008. Only papers in English, French, Portuguese and Spanish were included in the literature review. Studies excluded were those presented in conference proceedings, editorials and draft papers. The full search generated 320 abstracts relevant to pedestrian safety, which were screened to produce 26 full studies reviewed for this manual. The two experts who conducted the literature review grouped the interventions into three categories – proven, promising and insufficient evidence – based on the existing best practices in road safety. The Advisory Committee reviewed the categories and refined them based on the existing best practices in road safety policy and their expert knowledge.

Safe System approach

The Safe System approach recognizes that road transport is a complex system and places safety at its core *(2–7).* It also recognizes that humans, vehicles and the road infrastructure must interact in a way that ensures a high level of safety (see Fig. 1). A Safe System therefore *(2):*

- anticipates and accommodates human errors;
- incorporates road and vehicle designs that limit crash forces to levels that are within human tolerance to prevent death or serious injury;
- motivates those who design and maintain the roads, manufacture vehicles and administer safety programmes to share responsibility for safety with road users, so that when a crash occurs, remedies are sought throughout the system, rather than solely blaming the driver or other road users;
- pursues a commitment to proactive and continuous improvement of roads and vehicles so that the entire system is made safe rather than just locations or situations where crashes last occurred; and
- adheres to the underlying premise that the transport system should produce zero deaths or serious injuries and that safety should not be compromised for the sake of other factors such as cost or the desire for faster transport times.

Fig. 1 Safe System approach

Source: (8).


1

Module 1
Why is addressing pedestrian safety necessary?

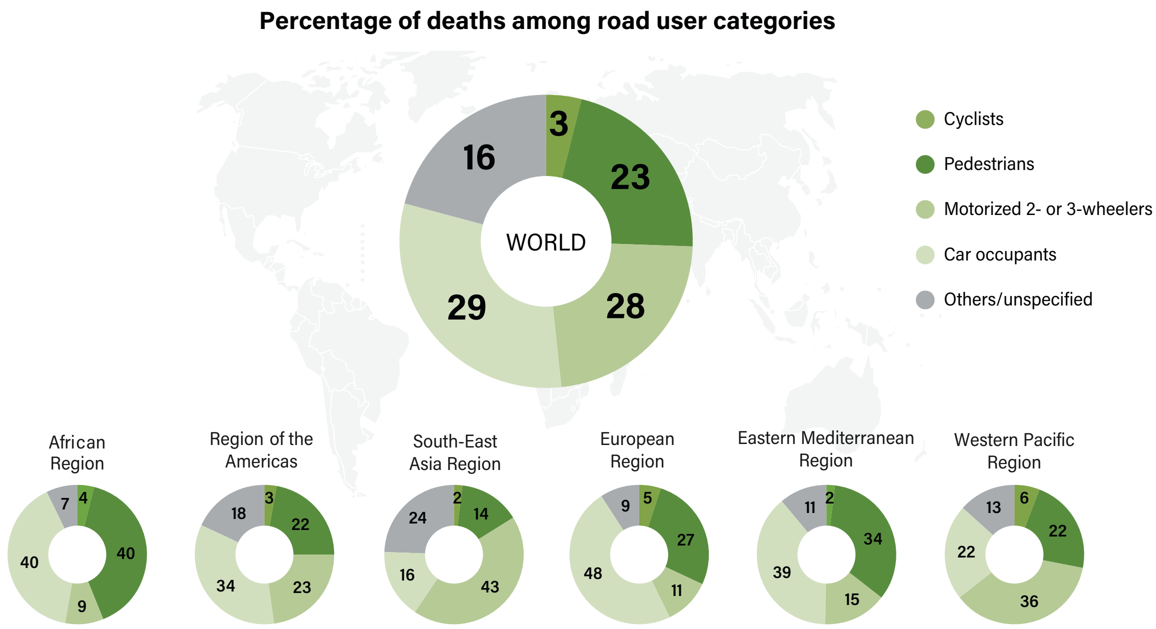
1.1 Magnitude of the pedestrian death and injury problem

This section describes the global magnitude of the pedestrian death and injury problem, including the proportion of pedestrian fatalities in relation to other road users; the demographic and socioeconomic characteristics of people who are killed or injured as pedestrians; and the places and times that collisions with pedestrians occur.

Roads remain unsafe for pedestrians in all parts of the world. Globally, pedestrian deaths have risen at nearly twice the rate of road crash deaths (12.9% increase from 2013 to 2016, compared with 6.6% increase for other road users) *(9)* and, per kilometre travelled, pedestrians are nine times more at risk of death than car occupants *(10).* In the United States of America, between 2008 and 2018 pedestrian deaths increased by 41% while deaths for other road users decreased by a modest 7% *(11,12).*

Based on estimated global road traffic fatalities, around 310 500 pedestrians were killed in road traffic crashes in 2016 *(13),* representing around 23% of all road traffic deaths (see Fig. 1.1). There is a clear geographic distribution of pedestrian mortality, with the proportion of pedestrians killed in relation to other road users being highest in the African Region (40%) and lowest in the South-East Asia Region (14%) *(13).*

Fig. 1.1 Road traffic deaths by type of road user, WHO region, 2016



Source: (13).

Pedestrian fatalities constitute around 30% of the deaths caused by road traffic crashes in India. The proportion of pedestrian fatalities in large cities (e.g. New Delhi and Mumbai) varies from 50–60% of all road traffic deaths, and is 20–30% on national and state highways *(14)*. A recent study of nine cities in India reported that the proportion of road traffic deaths that were pedestrians ranged from 22–46% of the total of such deaths *(15)*.

The wide variation in pedestrian deaths between and within countries underscores the need for a comprehensive analysis of existing road traffic injury data at country, city and institutional (e.g. hospital) level to generate an accurate picture of the magnitude of pedestrian fatalities and injuries.

1.2 Who is most affected?

The characteristics of pedestrians killed or injured in road crashes are briefly described in this section.

Age

Pedestrian deaths and injuries affect people of all ages, but some age groups may be represented disproportionately in certain settings. For example, in South Africa, where pedestrian injury is the leading cause of injury mortality among children, about 22% of all pedestrian deaths occur among children under the age of 15 years *(16)*. Another example from the United States shows that between 2009 and 2016, there were significant average annual increases in death rates among pedestrians aged 20–29 years (3.8%); 30–59 (5.1%) years; 60–69 years (5.6%); and 70 years and older (1.6%) *(11).*

In the state of Maharashtra, India, fatalities are highest for pedestrians aged 10–20 years (28.6%), followed by people aged 61–70 years (19.3%) *(17)*. And at the regional level, sub-Saharan Africa accounts for 35.2% of global child deaths caused by road traffic injuries *(18).*

Sex

Male pedestrians, both children and adults, have been found to be overrepresented in pedestrian collisions *(11).* For example, a study conducted in the United States found that males accounted for 70% of pedestrian deaths, with a fatality rate of 2.19 deaths per 100 000 population, compared with a female fatality rate of 0.91 per 100 000 *(19)*. A study conducted in Mexico found the pedestrian mortality rate to be higher among males (10.6 per 100 000 population) than females (4 per 100 000) *(20)*. A study of alcohol-impaired pedestrian patients in a South African hospital showed a male to female ratio of 2:1 *(21)*.

Socioeconomic status

Socioeconomic status is a significant determinant of pedestrian injury in all countries. In general, people from poorer communities tend to be at a higher risk of pedestrian injuries. For example, studies have shown that:

- In the United Kingdom, the risk of pedestrian injury for children in the lowest socioeconomic group was more than twice that of children of higher socioeconomic status groups *(22)*.
- In low-income neighbourhoods in Orange County, California, pedestrian crashes were four times more frequent than in higher income neighbourhoods *(23)*.

- In Hyderabad, India, children from the highest income households were significantly less likely to sustain pedestrian road traffic injuries than those from lower income households *(24)*.
- In the city of Memphis, United States, low income and poverty are associated with the largest numbers of child pedestrian crashes *(25)*.

1.3 Where do pedestrian collisions occur?

The locations of pedestrian collisions vary widely from one setting to another. For example, about 70% of all pedestrian deaths in European Union countries, and 76% in the United States, occur in urban areas *(26,27)*. In the United Kingdom, young pedestrians from urban areas were five times more likely to be involved in crashes than those in rural areas, and their death rate was twice as high *(28)*. This contrasts with a Chinese study, which found that pedestrians commuting in rural areas were more likely to suffer injuries than pedestrians commuting in urban areas *(29)*. Similarly, a study of university students in Cairo, Egypt, found that those living in rural areas were significantly more likely to suffer pedestrian injuries than those in urban areas *(30).* In India, 20–34% of road traffic crash victims on rural highways are pedestrians *(15)*.

1.4 When do pedestrian collisions occur?

Night-time travel is one of the greatest risk factors for pedestrians *(31,32)*. Twilight and the first hour of darkness typically see a high frequency of pedestrian collisions in most countries *(33)*. In some countries, more pedestrian collisions occur during weekdays than weekends, while in others, the reverse is true *(34)*. During the month of December in the United States, collisions are concentrated around twilight and the first hour of darkness throughout the week. In June, however, collisions are concentrated around twilight and the first hour of darkness on Fridays and Saturdays *(33)*.

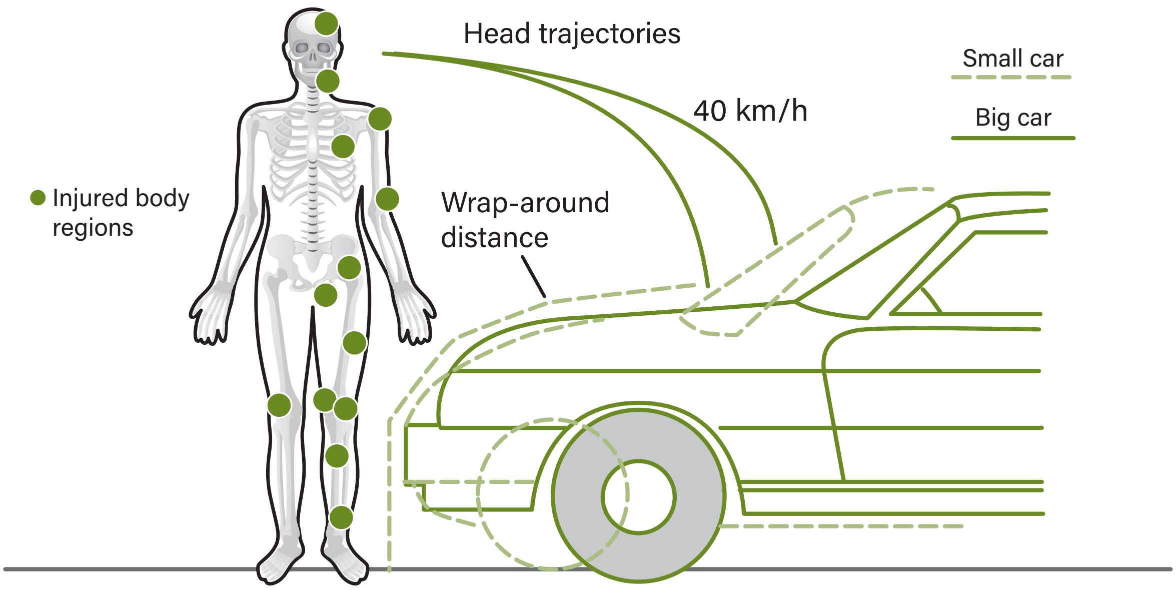
1.5 What happens in a pedestrian collision?

Most pedestrian-vehicle crashes involve frontal impacts *(35)*. Fig. 1.2 summarizes the contact points between the pedestrian and the car during a crash. It should be noted that during pedestrian-vehicle contact, the entire body wraps around the front of the car. An adult pedestrian is typically "run under" rather than "run over" by the striking car.

The sequence of events in a frontal impact is fairly well summarized in studies *(36)*. The starting point assumes a standing adult pedestrian who is struck by the front of a car:

- The first contact occurs between the bumper and either the leg or knee joint area, followed by thigh-to-bonnet edge contact.
- The lower extremity of the body is accelerated forwards, and the upper body is rotated and accelerated relative to the car.
- Consequently, the pelvis and thorax are struck by the bonnet edge and top, respectively.
- The head will hit the bonnet or windscreen at a velocity that is at, or close to, that of the striking car.
- The victim then falls to the ground.

Fig. 1.2 Distribution of injuries on the body of a pedestrian in a frontal car-pedestrian collision



Source: (36).

The most serious injuries are usually caused by the direct impact with the striking car rather than when the pedestrian is thrown to the road. The severity of injuries occurring to the head, brain, thorax, pelvis and extremities is influenced by:

- car impact speed;
- type of vehicle;
- stiffness and shape of the vehicle;
- nature of the front (such as the bumper height, bonnet height and length, windscreen frame);
- age and height of the pedestrian; and
- standing position of the pedestrian relative to the vehicle front *(36)*.

Motorcycles also contribute to pedestrian injuries. For example, in Brazil in 2007, motorcycles were involved in 22.8% of all fatal pedestrian crashes and were responsible for the deaths of 85 pedestrians (10% of the total) *(37)*. A similar proportion of motorcyclists have been found to be involved in pedestrian deaths in Indian cities *(38)*.

1.6 Risk factors

Key risk factors for pedestrian injury include lack of road infrastructure for pedestrians, speeding, alcohol impairment and inadequate visibility of pedestrians on roads.

Lack of pedestrian facilities in road design and land-use planning

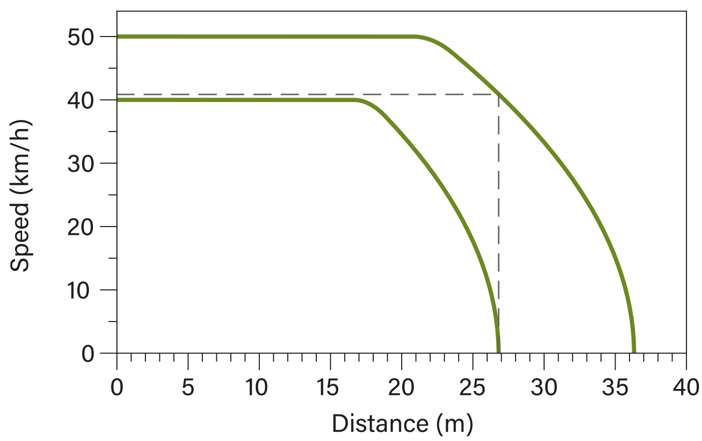
Pedestrian risk is increased when road design and land-use planning fail to provide facilities such as pavements or give adequate consideration to pedestrian access at intersections *(39–41)*. Infrastructure facilities and traffic control mechanisms that separate pedestrians from motor vehicles and enable pedestrians to cross roads safely are important to ensure pedestrian safety, and complement vehicle-speed and road-system management. A study in Kolkata, India, showed that high pedestrian volume and wider minor roads are associated with higher pedestrian fatalities *(42)*. A study in Ghana showed that 98% of pedestrian collisions occurred in locations far away from pedestrian crossings or where there were no pedestrian crossings *(43)*. A study in Malaysia showed that safe crossings are often not visible for adults and children in highly busy road environments *(44)*.

Environmental challenges such as uneven road surfaces, crowded intersections and stairs, and slippery surfaces increase the rate of pedestrian falls *(45)*. The mismatch of facilities with older pedestrians or those with disability is a serious barrier to pedestrian safety, and their needs must be considered when redesigning urban spaces.

Speed

Travelling speed and risk of pedestrian crash: The speed at which a car is travelling influences both crash risk and crash consequences. The effect on crash risk comes mainly from the relationship between speed and stopping distance. The higher the speed of a vehicle, the shorter the time a driver has to stop and avoid a crash, including hitting a pedestrian *(46)* (see Fig. 1.3). Taking into account the time needed for the driver to react to an emergency and to brake, a car travelling at 50 km/hr will typically require 36 m to stop, while a car travelling at 40 km/hr will stop in 27 m.

Fig. 1.3 Speed and stopping distance for emergency braking



Source: (46).

Fig. 1.3 represents an average situation in which a driver takes 1.5 seconds to realize there is a risk of a collision with a pedestrian and to brake. In some situations the driver may react more quickly, and the car may stop more rapidly, but in other situations, if the driver is not concentrating fully on the road ahead or the road is wet, the opposite will occur. If a car is travelling unusually fast, other road users such as a pedestrian waiting to cross the road may misjudge the speed of the approaching vehicle.

Impact speed and pedestrian injury severity: Recent evidence shows that an adult pedestrian hit by a car moving at 30 km/hr has 99% chance of survival and if hit at 50 km/hr has 80% chance of survival *(47).* Generally, the risk of pedestrian death increases more rapidly for any small increase in the impact speed between 30 and 70 km/hr. A meta-analysis of 20 studies assessing the risk of fatality for pedestrians reported that for every 1 km/hr above 30 km/hr that speed increases, the chance of pedestrian death increases by 11% *(48).* It is within this context that a speed of 30–40 km/hr is recommended in areas with high pedestrian traffic.

Factors influencing vehicle speed reveal how the interaction between the vehicle, road environment and road user create risks for pedestrians. The key aspects include *(49):*

- driver-related factors (age, sex, alcohol level, number of people in the vehicle);
- road- and vehicle-related factors (road layout, surface quality, vehicle power, maximum speed); and
- traffic- and environment-related factors (traffic density and composition, prevailing speed, weather conditions).

Speed management is important for addressing pedestrian safety around the world. To keep drivers' travelling speed under the set speed limits, appropriate speed management (e.g. speed calming measures and enforcement) is also essential in areas with high pedestrian traffic. Key measures for managing speed include setting speed limits to 30–40 km/hr in residential and high pedestrian traffic areas, enforcing traffic rules on speed limits and implementing traffic calming measures. These measures are examined in detail in Module 2.

Inadequate visibility of pedestrians

The issue of pedestrians not being properly visible is frequently cited in literature as a risk for pedestrian injury. Inadequate visibility of pedestrians arises from *(50):*

- inadequate, or lack of, roadway lighting;
- vehicles and bicycles not equipped with lights;
- pedestrians not wearing reflective accessories or brightly coloured clothes, especially at night and at dawn or dusk; and
- pedestrians sharing road space with fast-moving vehicles.

Alcohol impairment

Impairment by alcohol is an important factor influencing both the risk of a road traffic crash as well as the severity and outcome of injuries that result from it *(49,50)*. Alcohol consumption results in impairment, which increases the likelihood of a crash because it produces poor judgement, increases reaction time, lowers vigilance and decreases visual acuity *(50).* Alcohol consumption is also associated with excessive speed *(51,52)*. It is important to note that alcohol impairment as a risk factor is not limited to drivers of vehicles but is also important for pedestrians. Like motor vehicle drivers, a pedestrian's risk of crash involvement rises with increasing BAC *(53)*.

Alcohol impairment and pedestrian injury is a problem in several countries. For example:

- Approximately one third of all fatally injured adult pedestrians in Australia have a BAC exceeding 0.08 to 0.1 g/dL *(53)*.
- 35% of fatally injured pedestrians in the United States in 2009 had a BAC above 0.08 g/dL, compared with 13% of drivers involved in fatal pedestrian crashes *(26)*.
- Data from the United Kingdom show that 46% of fatally injured pedestrians had BAC in excess of 0.09 g/dL in 1997 compared with 39% a decade earlier *(34).*
- 20% of injured pedestrians treated in hospital emergency departments in Eldoret town in Kenya had a BAC level exceeding the legal limit (for drivers) of 0.05 g/dL *(54).*
- 59% of pedestrian patients in a hospital in South Africa were impaired above the legal limit of 0.08 g/dL *(16)*. Recent data from South Africa indicate that fatally injured pedestrians were more likely than fatally injured drivers to have alcohol in their blood.
- In Serbia, it has been suggested to combine efforts to curb driving under the influence of alcohol with measures to address pedestrian BAC levels, in order to further reduce pedestrian mortality *(55)*.

Other risk factors

Several other factors that contribute to pedestrian injury include *(36,56–60):*

- driver distraction, including mobile phone use;
- driver fatigue;
- pedestrian-vehicle conflict at pedestrian crossing points;
- reduced reaction time and reduced walking speed for the older people;
- inability of children to gauge vehicle speed and other relevant information in order to cross the street safely alone;
- pedestrian distraction, including mobile phone use;
- failure of drivers to respect right-of-way for pedestrians, including failure to yield at pedestrian crossings;
- lack of safety features such as pedestrian friendly bumpers on vehicles; and
- quiet (electric) vehicles, whose presence cannot be detected by normal auditory means.

Whatever the country and circumstances, the severity of pedestrian injury depends on five factors:

- energy dissipated in the collision, which is related to the speed of the vehicle at the moment of impact;
- shape and stiffness of the vehicle surfaces striking the impacted body areas;
- post-impact kinematics of the pedestrian's body;
- possible impact against the ground or a secondary obstacle; and
- pedestrian's individual capacity to withstand the impact or impacts *(61)*.

1.7 Summary

Globally, roads are not safe for pedestrians, and the situation is worsening. Pedestrian deaths have increased at nearly twice the rate of other types of road crash deaths: between 2013 and 2016 there was a 12.9% increase globally, compared with a 6.6% increase in deaths for other road users.

The wide variation in pedestrian deaths between and within countries underscores the need for a comprehensive analysis of existing road traffic injury data at country, city and institutional (e.g. hospital) level to generate an accurate picture of the magnitude of pedestrian fatalities and injuries in local settings.

Pedestrian risk is increased when road design and land-use planning fail to provide facilities such as pavements or give adequate consideration of pedestrian access at intersections. Infrastructure facilities and traffic control mechanisms that separate pedestrians from motor vehicles and enable pedestrians to cross roads safely are important to ensure pedestrian safety, complementing vehicle speed and road system management. The failure to provide adequate facilities for older pedestrians or those with disabilities is a serious barrier to pedestrian safety, and their needs must be considered when redesigning urban spaces.


2

Module 2 Evidence-based pedestrian safety interventions

2.1 An overview of effective pedestrian safety interventions

There are several engineering and behavioural interventions that are effective in improving pedestrian safety (see Table 2.1 for a summary of these interventions). This table is based on a review of evidence on pedestrian safety from January 2008 through December 2019, resulting in 26 full studies that were considered in this update. The effectiveness of interventions relates to the reduction of fatalities or injuries as well as other measurable change(s) in the behaviour of the road user targeted by the intervention. The evidence on interventions is categorized into one of three groups: proven, promising or insufficient evidence. The assessment of effectiveness and impact was made using several tools developed in evidence-based medicine and policy research. For the purpose of this document the following intervention category definitions are used:

- **Proven:** Evidence from robust studies such as randomized controlled trials, systematic reviews or case-control studies shows that these interventions are effective in reducing pedestrian fatalities and injuries, or in bringing about desired behaviour change.
- **Promising:** Evidence from robust studies shows that some pedestrian safety benefits have resulted from these interventions, but further evaluation from diverse settings is required and caution is thus needed when implementing these interventions.
- **Insufficient evidence:** Evaluation of an intervention has not reached a firm conclusion about its effectiveness *(62)*.

Each intervention's effectiveness is assessed by the degree to which it can reduce fatalities and injuries, as well as effect changes in behaviour, attitudes and knowledge. Table 2.1 categorizes pedestrian safety strategies.

Table 2.1 Key measures and specific interventions for improving pedestrian safety

Key measures	Specific interventions	Effectiveness		
		Proven	Promising	Insufficient evidence
Reduce pedestrian exposure to vehicular traffic	Provide pavements	■		
	Install and/or upgrade traffic and pedestrian signals	■		
	Construct pedestrian refuge islands and raised medians (central reservations)	■		
	Construct enhanced marked crossings		■	
	Provide vehicle restriction/diversion measures	■		
	Install overpasses/underpasses (context specific)[a]	■		
	Improve mass transit route design	■		
	Reduce traffic volumes by encouraging people to make journeys on public transport, on foot or by bicycle (for distances and purposes where these options work well) instead of using personal motorized transport	■		
Reduce vehicle speeds	Reduce speed limits	■		
	Implement system-wide lower speed, e.g. 30 km/hr, programmes for an entire place and not only for selected sites	■		
	Implement road-narrowing measures		■	
	Install speed management measures at road sections (mid blocks)	■		
	Install speed management measures at intersections	■		
	Provide school route improvements		■	
Improve sight distance and /or visibility between motor vehicles and pedestrians	Provide crossing enhancements	■		
	Implement lighting/crossing illumination measures	■		
	Reduce or eliminate obstruction by physical objects including parked vehicles		■	
	Install signals to alert motorists that pedestrians are crossing		■	
	Improve visibility of pedestrians		■	
Improve pedestrian and motorist safety awareness and behaviour	Provide education, outreach and training[b]	■		
	Develop and/or enforce traffic laws on speed, drinking and driving, pedestrian right-of-way, commercial roadside activity and traffic control	■		
	Implement "walking school bus" programmes		■	

Key measures	Specific interventions	Effectiveness		
		Proven	Promising	Insufficient evidence
Improve vehicle design for pedestrian protection	Develop vehicle safety standards and laws for pedestrian protection			
	Enforce vehicle safety standards and laws for pedestrian protection			
	Publicize consumer information on pedestrian safety by make and model of car, e.g. results of new car assessment programmes			
Improve care for injured pedestrians	Organize pre-hospital trauma care systems			
	Establish inclusive trauma care systems			
	Offer early rehabilitation services			

Notes:

[a] Overpasses and underpasses are effective when pedestrians use them. Pedestrians do not like to use overpasses and underpasses unless it is convenient.

[b] Education, outreach and training are effective in conjunction with appropriate infrastructure and improved enforcement.

Sources: (61–69).

A recent systematic review assessed the effectiveness of interventions globally to reduce pedestrian road traffic injuries through altering the road environment, legislation and enforcement, road user behaviour and education, and combinations of these. Overall, the assessment showed that the first two interventions, i.e. altering the road environment, and legislation and enforcement interventions alone and in combination with road user behaviour/education remedies may improve pedestrian safety *(62)*.

2.2 Description of interventions

2.2.1 Reducing pedestrian exposure to vehicular traffic

There are several specific engineering measures that reduce pedestrian exposure to vehicular traffic. Most of these measures involve separating pedestrians from vehicles or reducing traffic volume. This section discusses pavements/footpaths, marked crossings, overpasses and underpasses, and mass transport routes as key strategies to reduce pedestrian exposure to vehicular traffic. These interventions are good starting points for action, but pedestrian safety will be most improved when they are implemented in conjunction with other measures such as reducing vehicle speed.

Pavements/footpaths

Pavements separate pedestrians from motorized vehicles as well as bicycles. They provide space for different types of pedestrians to walk, run, play, meet and talk. Enhancing the quality of city pavements not only attracts more pedestrians, but also helps to create enjoyable public spaces where people want to spend their time. Separate pavements are recommended for roads where motorized vehicle speeds are more than 15–20 km/hr.

Studies show that pavements improve both pedestrian safety and increase walking:

- Pedestrian crashes decrease where there are pavements and raised medians. A study conducted in the United States found that pedestrian crashes were more than twice as likely to occur at locations without pavements compared with similar locations with a pavement *(64).* Residential areas without pavements had 23% of all pedestrian-vehicle crashes but only 3% of pedestrian-vehicle exposures *(63)*.
- Properly constructed pavements and pathways encourage people to walk *(65).*

To maximize the benefits of pavements/footpaths for pedestrian safety, they should:

- be part of every new and renovated roadway;
- be provided on streets that currently do not have pavements, including providing shoulders on rural roads;
- be provided on both sides of the road;
- consist of a hard, level surface;
- be designed according to existing local guidelines in relation to width, depth, surface type and placement;
- be separated from other vehicles with a kerb, buffer zone, or both;
- be continuous and accessible to all pedestrians;
- be adequately maintained;
- have adequate width (as narrow pavements may be an additional road safety hazard);
- include kerb ramps (as they are important in addressing the needs of people in wheelchairs and pedestrians with mobility impairments);
- be free from obstructions (e.g. lamp posts and road signs), traders and other obstructions; and
- include demarcations by road user type when shared by pedestrians and cyclists.

In addition to street redesign interventions, the following measures should also be considered:

- Enforcement of traffic laws in order to ensure that motorists respect pedestrian right-of-way at raised pedestrian crossings.
- Raising awareness and implementing education programmes to inform motorists about the new sequencing of vehicle/pedestrian movement at traffic signals as well as traffic laws for the protection of pedestrians.
- Implementation of additional design measures to enhance pedestrian safety such as installing bollards on right turns.
- Kerb extensions reinforce the existence and prominence of pedestrian crossings; reinforce the presence of pedestrians; reduce the width of the road that pedestrians have to cross; improve visibility between motorists and pedestrians.

Marked crossings

Marked crossings separate pedestrians from vehicular traffic for a brief time period while they cross the street. The purpose of a marked crossing is to indicate the optimal or preferred location for pedestrians to cross. Marked crossings help to indicate pedestrian right-of-way and motorists' need to yield to pedestrians at these points. Marked crossings are commonly installed at signalized intersections, as well as other high-volume pedestrian crossing locations such as school zones, busy markets etc. They should, however, be installed in conjunction with other physical roadway enhancements that reinforce the crossing and/or reduce vehicle speeds. Marked crossings result in improved safety when motorized vehicle drivers comply with the speed reduction advice or don't violate the red light signal.

There are several important issues for practitioners and decision-makers to consider when installing crossings:

- Markings on crossings are unlikely to increase pedestrian safety without related enhancements such as raised crossing islands and traffic signals.
- Marked crossings are not appropriate where traffic speed is high.
- Marked crossings on roads with more than two lanes may increase the risk of pedestrian-vehicle crashes.
- Crossing locations should be convenient for pedestrians and accessible for pedestrians in wheelchairs. Pedestrian movements and "desire lines" (the most direct, or shortest path between two locations) can be analysed to identify optimum locations for crossings.
- Marked crossings should guide pedestrians to cross at locations where there is street lighting at night.
- Detectable warnings should be installed to advise pedestrians with visual impairments as to where the kerb ramp ends and the street begins. The warnings should also indicate when the traffic lights will change.
- There should be adequate visibility between vehicles and pedestrians. For example, night-time pedestrian crossings should be properly illuminated in order to help drivers to see pedestrians.

Overpasses and underpasses

Pedestrian overpasses and underpasses are bridges and tunnels that allow for uninterrupted flow that is separate from vehicular traffic. This measure is used primarily in areas with high pedestrian volumes or on high-speed roads. Overpasses are suitable when the topography allows for a structure without ramps, for example, an overpass over a below ground-level road. Overpasses with multiple stairs are not user friendly for older or disabled pedestrians. Underpasses need to be designed in such a way as to offer a sense of being open and accessible. In Tokyo, reductions in vehicle-pedestrian crashes of up to 91% were found following the implementation of overpasses and fencing *(63)*.

The effectiveness of these measures depends largely upon the likelihood that they will be used by most of the pedestrians crossing the street. Pedestrians generally do not use these facilities if a more direct route is available. Tall fences and other pedestrian barriers are used to channel pedestrians to the overpass or underpass. These are not always effective, since pedestrians find ways to go around the barriers and cross at intersections. The level of use depends on convenience, security and walking distances compared with alternative crossing locations. Thus, to ensure usability of over- and underpasses additional attention is required for security, improved lighting, cleanliness and accessibility (*66–71*). However, such designs are not always appreciated by pedestrians as they are sometimes not practical or raise security concerns. A respondent in a qualitative study noted: "If I want to use pedestrian overpasses, I have to walk 50–100 m further down the street, go up the stairs about 50 steps, and then come down; so, I definitely do not use the overpass and cross the street!" *(66)*.

The following issues arise with implementation of overpasses and underpasses:

- Ramps must be designed to accommodate pedestrians in wheelchairs.
- Underpasses can be affected by flooding, and may quickly become dirty without regular maintenance.
- Underpasses are often dark, and in secluded places. They may be targeted by gangs or other perpetrators of interpersonal violence, and, for this reason, people, especially women, who perceive a high risk of assault often avoid them. Hence, overpasses and underpasses should be well-lit and secure, to maximize personal security and therefore utilization.

Mass transport routes

Pedestrian safety is a key consideration in the design of any mass transport system, including for routes and stops. Mass transport routes are usually located on major arterial roads, which are the most dangerous types of urban streets *(72)*, and though travelling by public transport may be one of the safest modes, passengers are at a high risk of crashes when walking to and from stations or stops *(73)*. Safe pedestrian paths leading to bus and metro stops and adequate safety measures around public transport systems (including safe crossing facilities) are required to ensure pedestrian safety.

2.2.2 Reducing vehicle speeds

One of the most effective ways to improve pedestrian safety is to reduce vehicle speed *(74)*, which is a key risk factor for pedestrian injury. If possible, speed management measures should be used alongside measures to reduce pedestrian exposure to vehicular traffic. Even if it is not possible to reduce pedestrian exposure to traffic, speed management remains an effective measure to reduce pedestrian traffic risk, and a core component of the Safe System approach. For example, a study conducted in Toronto, Canada, which examined the effect of 40 km/hr and 30 km/hr speed limits on pedestrian-vehicle collisions, revealed a decrease in such collisions of 28% *(75).*

Speed management involves much more than setting and enforcing appropriate speed limits. It deploys a range of engineering, enforcement and education measures, with the aim of balancing safety with efficient vehicle speeds on the road network. Detailed guidance on the effectiveness and implementation of speed management strategies can be found in *Speed management (76)*, and WHO's *Speed management: a road safety manual for decision-makers and practitioners (77).* There is a growing effort to implement system-wide lower speeds of 30 km/hr or even lower for entire geographical areas instead of focusing on individual streets *(78)*.

The engineering approach to speed management consists of several specific traffic calming measures – physical treatments to roads as well as perceptual treatments and speed limit reductions aimed at reducing vehicle speeds and sometimes traffic volume *(79)*. Traffic calming measures are generally of two types:

- Those that require motorists to change their direction of travel by moving either to the left or right (horizontal deflection); and
- Those that require motorists to change elevation by either going up or down (vertical deflection).

Traffic calming measures vary from minor modifications to local streets, up to area-wide changes and major rebuilding works *(79)*. Such efforts may include moderate speed reductions and street design changes, with various degrees of success in reducing pedestrian crashes and traffic volume. Several studies show a reduction in pedestrian-vehicle conflicts and crashes associated with refuge islands, marked crossings with a raised median, road narrowing, staggered lanes, road humps and junction redesign *(63,80–82)*.

When choosing traffic calming measures it is important to bear the following in mind *(79)*:

- A combination of traffic calming measures provides the greatest benefit. Ideally, they should be applied on various streets and area-wide, rather than in one or two isolated locations.
- The design of traffic calming measures tends to be context specific, deploying a variety of measures appropriate to different types of roads. It is therefore important to apply measures on the street types and areas (e.g. residential) for which they are designed. Some are appropriate at intersections, some in low-volume residential areas, and others are meant to be applied area-wide. Table 2.2 provides an overview of the application of various calming measures to road types – arterial and local – as well as their anticipated impact on traffic volume.
- Different measures are appropriate for addressing either speed or traffic volume. It is therefore important to determine whether the aim is to reduce speed or traffic volume, or both (see Table 2.2).
- Speed humps, traffic circles and other traffic calming measures are perceived by some traffic engineers, neighbourhood residents and members of the media as obstacles. As a result, there may be opposition to installing these measures. Resident input and consensus may be necessary when planning residential traffic calming measures.
- Traffic calming interventions alone do not improve conditions for pedestrians. Other issues need to be addressed, such as law enforcement and provision of adequate street lighting.

Table 2.2 Traffic calming measures – application and impact

Type	Speed reduction can be applied to:		Impact on traffic volume
	Arterial roads	Local roads	
Speed hump	No	Yes	Possible
Speed table	With caution	Yes	Possible
Raised crosswalk	Yes	Yes	Possible
Raised intersection	With caution	Yes	Possible
Textured pavements	Yes	Yes	Possible
Speed cushion	With caution	Yes	Possible
Rumble strips	Yes	Yes	No
Traffic (mini) circle	No	Yes	Possible
Roundabout	Yes	Yes	Not likely
Chicanes	No	Yes	Yes
Realigned intersection	Yes	Yes	Possible
Tight corner radii	Yes	Yes	Possible
Centre-island narrowing	Yes	Yes	Possible
Chokers	Yes	Yes	Possible

Type	Speed reduction can be applied to:		Impact on traffic volume
	Arterial roads	Local roads	
Road diets (i.e. lane reduction)	Yes	Yes	Yes
Speed limits	Yes	Yes	No
Speed alerts, enforcement	Yes	Yes	No
Perceptual design	Yes	Yes	Possible
Warning signs	Yes	Yes	No
Half closure	Yes	Yes	Yes
Diagonal diverters	Yes	Yes	Yes
Lateral shift	Yes	Yes	No
Median barriers	Yes	No	Yes
Gateway treatments	Yes	No	No
Traffic signal coordination	Yes	No	No
Vehicle-activated signs	Yes	No	No

Source: (79).

Raised pedestrian crossings

There are two key ways to reduce fatal and serious pedestrian injuries: the first is to separate pedestrians from motorized traffic, and the second is to slow vehicle speed to a level low enough that if a collision does occur, it will not result in fatal or serious injury. Raised pedestrian crossings force vehicles to slow to speeds low enough that a pedestrian would survive a collision. Reductions in pedestrian crashes of around 40% could be expected from the installation of a raised crossing *(65)*. The presence of high visibility crosswalks can modify driving behaviour, thus reducing the risk of vehicle-pedestrian conflicts *(83).*

Key decision-maker and practitioner considerations are that raised pedestrian crossings:

- should be clearly marked and advance warning provided;
- are not usually suitable for very high-speed environments;
- are of most benefit if there other traffic calming measures deployed in advance of the crossing.

Road narrowing

There are a number of ways to narrow roads, including providing kerb extensions, installing refuge islands, and widening footpaths by narrowing or even removing lanes. Although a high-cost intervention, treatments that include widening footpaths have the additional benefit of providing higher quality facilities for pedestrians. Road narrowing has a double benefit of reducing both vehicular traffic speeds and pedestrian crossing distances. The safety impact of road narrowing depends on the treatments used. For example, refuge islands can be expected to reduce crashes by around 40% *(65)*.

2.2.3 Improving the visibility of pedestrians

There are a number of engineering and behavioural measures that make pedestrians more visible to motorists, especially during dusk, dawn, and at night *(48,61,63)*. These measures include:

- Providing crossing enhancements such as raised crossing islands and traffic signals.
- Implementing lighting and/or crossing illumination measures. Increasing intensity of road lighting improves visibility of pedestrians at night, especially at pedestrian crossings. This intervention has been associated with significant reductions in night-time pedestrian crashes. For example, a study in Australia reported a 59% reduction in pedestrian crashes following improvement in road lighting *(63)*.
- Removing or repositioning physical objects that affect visibility, such as trees and billboards that make it difficult for drivers to see pedestrians. Alternatively, kerb extensions can be used to safely place pedestrians in a more visible location prior to crossing and to provide better sight lines to observe traffic. These have the additional advantage of reducing the crossing distance for pedestrians and narrowing the road, which may slow vehicle speed.
- Installing signals to alert motorists that pedestrians might be crossing. Pedestrian-activated signals may be appropriate at locations with sporadic pedestrian traffic *(27)*.
- Improving visibility of pedestrians in low light or dark conditions by selecting light-coloured clothing as well as adding reflective materials to backpacks, shoes and clothing.
- Raising awareness among pedestrians and drivers, through public service announcements and other media, about the importance of pedestrian visibility, especially at night.

2.2.4 Improving pedestrian and motorist safety awareness and behaviour

Changing the attitudes and behaviour of drivers and pedestrians is a complex, long-term undertaking that requires a variety of interventions that are most effective when implemented alongside other measures described in this module, including speed management and reducing pedestrian exposure to vehicular traffic.

Education, outreach and training

Safe road-user behaviour and a reduction in pedestrian fatalities depend on engineering and land-use planning measures, knowledge and skills, community support, perception of vulnerability and risk, social norms and models, and law enforcement *(44,84)*. It is therefore important for practitioners and decision-makers to remember that road safety education is an adjunct to other measures, rather than a stand-alone intervention.

Outreach: The school-to-home journey is a point of considerable exposure and risk for children. An important question to consider is when children are most at risk – what time of the day, which day of the week, and which month of the year? Child pedestrians walking alongside or among vehicular traffic are at risk for many reasons: they often lack the ability to distinguish between safe and unsafe crossing gaps and sites, putting them at risk as they cross the road; they may be distracted or be at risk from distracted drivers using their mobile phones *(85)*. One strategy to improve the safety of school children is the use of a walking school bus (WSB) (see Box 2.1).

Box 2.1 Walking school buses as a form of active transport for children

Walking school buses (WSBs) offer a potentially healthier way for children to get to school while reducing traffic congestion. One study reviewed 12 WSBs (identified through online and manual literature searches) involving a total of 9169 children. Study aims, designs, methods, outcomes, barriers and facilitators were examined.

WSBs were found to be associated with increased prevalence of walking to school and general activity levels, although not always significantly. Time constraints emerged as barriers to WSBs, impacting on recruitment of volunteers and children. Benefits of WSBs included children enjoying socializing and interacting with the environment.

Preliminary evidence of the health value of WSBs was demonstrated, along with recommendations for the design of future studies. By tackling barriers such as time constraints, volunteer recruitment and parents' safety concerns (while at the same time increasing convenience and time savings for families), future WSBs are likely to be more sustainable and taken up by more schools.

Source: (86).

Mass media campaigns: These can be used to inform the public about pedestrian safety legislation, risk factors, impact of collisions and solutions. Targeted and planned mass media and social marketing campaigns informing the public about pedestrian safety laws and risk factors are necessary to improve driver and pedestrian behaviour and enhance understanding of traffic issues such as traffic signs and rights-of-way for all road users *(67)*. Information alone is rarely sufficient to bring about changes in road user behaviour; communications should be supported by strong legislation, including targeted law enforcement operations.

Traffic law enforcement

Traffic laws affecting pedestrian safety are largely aimed at controlling pedestrian and driver behaviour at intersections, crossings and other locations *(67)*. Comprehensive legislation is a key element of pedestrian safety, but legislation alone is not likely to facilitate behaviour change in the absence of law enforcement and adequate penalties. Driver and pedestrian compliance with laws critical to pedestrian safety – such as legal vehicle speed limits, drinking and driving regulations, red light signal compliance and pedestrian traffic control signals – are motivated in part by the perceived risk of detection, i.e. law enforcement, and in part by the perceived severity of the penalties *(84)*.

Motorists' failure to obey posted speed limits contributes substantially to pedestrian collisions and injuries, especially in high pedestrian use areas, which are often associated with lower speed limits. In addition to enforcement of speed limits by the police, there are also physical measures related to the road and the vehicle that need to be implemented, for example speed bumps, which contribute to compliance with maximum posted speed limits. Consistent and highly visible law enforcement operations through a mix of visible patrols and fixed cameras are therefore essential *(77)*. Similarly, pedestrians should also follow regulations, such as stopping when the traffic light is red.

Alcohol-impaired drivers and pedestrians create injury risk for themselves and other road users. Strict legislation and complementary activities that can help reduce pedestrian road traffic injuries related to alcohol include the following *(50,67)*:

- Conducting mass-media campaigns on drinking and driving, including informing the public about drinking and driving regulations and penalties.
- Setting and enforcing BAC limits for the general driving population (0.05 g/dL) and lower limits for young and inexperienced drivers.
- Setting and enforcing minimum drinking-age laws.
- Regulating and enforcing laws on availability of alcohol.
- Enforcing BAC limits through random breath testing and sobriety checks, and implementing penalties for offenders.
- Enforcing laws on being drunk in public places, which will cover drivers, pedestrians and other members of the public.
- Conducting briefing interventions for injured people who come into emergency rooms with alcohol-related problems, including pedestrians, drivers and other patients.
- Rehabilitating high-risk offenders, i.e. those with BAC levels in excess of 0.15 g/dL.

2.2.5 Improving vehicle design for pedestrian safety

Motor vehicles have become increasingly safe for occupants due to improvements in vehicle design. Until recently, vehicle design incorporated few features to protect pedestrians, but there is an increasing effort to include design elements that reduce the likelihood of pedestrian collision and/or reduce the severity of pedestrian injury in the event that a vehicle-pedestrian crash does occur.

Collision prevention by vehicle design: The "brake assist" vehicle feature improves emergency braking ability and reduces the chance of collision. Brake assist activates when a sensor detects an emergency situation, indicated by unusually fast brake pedal activation and/or unusually hard pressure on the brake pedal. Brake assist, which is now fitted as standard to most new cars, can prevent some collisions with a pedestrian or at least reduce the impact speed of a collision. An evaluation in France concluded that cars equipped with brake assist had a 10% lower involvement in pedestrian fatalities than cars without it *(87)*.

Brake assist only activates, however, if the driver attempts to brake, which may not happen if the driver does not perceive a risk. In 45% of fatal pedestrian collisions in Adelaide, Australia, for example, drivers reported that they took no evasive action, typically because they did not see the pedestrian before impact or realize that a collision was likely *(88).*

Autonomous emergency braking (AEB) is a more recent development in pedestrian-protective vehicle design. Cars with AEB have sensors, usually mounted behind the grille and/or high behind the windscreen, that scan the road and roadside ahead of the car. If the sensors detect a risk of collision with a pedestrian (or vehicle) in front of the car, the driver is warned and/or the brakes are automatically applied *(89).*

2.2.6 Providing care for injured pedestrians

Initiation of swift post-crash care minimizes the risk of severe injury and death. While general pre-hospital care standards – such as a quick response time and the application of uniform treatment protocols – are effective for minimizing the risk of severe injury and death associated with road crashes, three interventions specific to pedestrian safety have been proven: organizing pre-hospital trauma care systems; establishing inclusive trauma care systems; and offering early rehabilitation services.

2.3 Summary

This module has presented evidence-based pedestrian safety measures, including reducing vehicle speed and pedestrian exposure to vehicular traffic; improving pedestrian visibility, motorist and pedestrian awareness and behaviour, and vehicle design for pedestrian protection; and providing care to injured pedestrians.

There are several specific engineering measures that reduce pedestrian exposure to vehicular traffic and most involve separating pedestrians from vehicles or reducing traffic volume.

Speed management is important for addressing pedestrian safety around the world and involves much more than setting and enforcing appropriate speed limits. It deploys a range engineering, enforcement and education measures in order to balance safety with efficient vehicle speeds on the road network.

Overall, road environment, legislation and enforcement interventions – both alone and in combination with road user behaviour/education remedies – can improve pedestrian safety.

Finally, pedestrian safety is a key issue to consider in the design of any mass transport system, including routes and stops which are often on major arterial roads.


3

Module 3
Implementing pedestrian safety interventions

3.1 Cycle of improvement

Improving road safety is a continuous cycle of planning, implementation and evaluation, and is never a one-off undertaking. There are opportunities as well as unexpected challenges that need to be managed as this cycle evolves in each country. Implementing continuous road safety improvement begins with assessing the existing system, followed by the development, implementation, evaluation and refinement of a national or a local plan of action. In addition to identifying and prioritizing necessary actions, other essential elements include human and financial resources, the sharing of responsibility among different agencies, and political commitment *(2)*.

3.1.1 Pathways to change

Applying the Safe System approach to road safety results in a complex set of interacting interventions that make them difficult – and sometimes unethical – to implement and evaluate using traditional research methods such as randomized controlled trials. For this reason, some researchers have proposed that "understanding the public health intervention's underlying theory of change and its related uncertainties may improve the evaluation of complex health interventions" *(90)*.

A theory of change is therefore basically the pathway(s) that will be followed to achieve the objective of a programme. It "explains how activities are understood to produce a series of results that contribute to achieving the final intended impacts. It can be developed for any level of intervention implementation – an event, a project, a programme, a policy, a strategy or an organization" *(91)* or the evaluation of such interventions or set of interventions (impact evaluation). It encourages "systems thinking" through the understanding of the complex social change processes, different perspectives, assumptions and the contexts needed to optimize success.

A theory of change is a systematic approach to understanding the pathway(s) to change in order to reach a long-term goal. It should always begin with a good situational assessment in order to understand the causes, risk factors, opportunities and challenges in the local situation where an intervention is to be implemented. It should then be guided by a participatory approach – bringing together multiple key stakeholders, through a workshop, for example, to discuss the proposed approaches or interventions that need to be implemented to optimize impact.

Although developing a theory of change is an iterative process, and there are many ways it can be developed, it should include the following basic steps *(92)*:

1. Identify the long-term outcome
2. Develop a pathway of change
3. Operationalize outcomes
4. Develop interventions
5. Articulate assumptions
6. Monitor and evaluate the process.

As a final output of stakeholder discussions, a visual map of the change being explored should be developed to show the relationships between proposed actions/interventions and outcomes and how these interact in order to achieve the goal.

The benefits of developing a realistic and implementable theory of change are articulated in Box 3.1. In general, this process challenges the status quo and gets stakeholders to "think outside the box" so that mistakes are not made when interventions are implemented. It also forces stakeholders to think about resources and how these will be best utilized to bring about the required change. Finally, the process develops a shared understanding of the actions to be taken and expected outcomes on one hand and accountability on the other.

Box 3.1 How a theory of change would benefit your programme

It provides:

- A clear and testable hypothesis about how change will occur that not only allows you to be **accountable for results**, but also makes your results more credible because they were predicted to occur in a certain way.
- A **visual representation** of the change you want to see in your community and how you expect it to come about.
- A **blueprint for evaluation** with measurable indicators of success identified.
- An **agreement among stakeholders** about what defines success and what it takes to get there.
- A powerful **communication tool** to capture the complexity of your initiative.

Source: (91).

3.2 How to assess the situation

A situational assessment for pedestrian safety should include the following activities:

- Describing the magnitude, trends and patterns of pedestrian fatalities and injuries.
- Analysing risk and protective factors for pedestrian injuries and fatalities.
- Examining the times and places where pedestrian injuries and fatalities occur.
- Describing the modes of transport involved in conflicts with pedestrians.
- Identifying and assessing existing pedestrian safety programmes and institutions to identify gaps and areas to improve, as well as those to maintain.
- Identifying contextual factors related to politics, environment, economics and capacity that may facilitate or hinder the implementation of pedestrian safety measures.

Key contributions to the situational assessment will come from a range of existing data sources, including from agencies responsible for roads and transport, law enforcement, urban and regional planning, public health and finance, and from road safety nongovernmental organizations. Additional data in the form of observational studies, surveys and/or road safety audits may be required to supplement existing data sources.

3.3 Challenges in implementing interventions for pedestrian safety

There are several challenges in implementing pedestrian road safety interventions, including:

- Lack of adequate infrastructure for pedestrians in most settings.
- Footpaths are being taken over by e-mobility, putting pedestrians at risk. There appear to be growing issues for pedestrian safety, and the safeness of the "smart city" concept is debatable *(93)*. While e-scooters and e-bikes may reduce fossil fuel use and greenhouse gas emissions (depending on which mode of transport they drive a reduction in – e.g. public or personal), they are commonly used on footpaths even where it is not legal *(94)*, and in some locations are allowed on footpaths legally but not on roads *(94,95)*. The use of these vehicles on pavements degrades pedestrian amenity and puts pedestrian safety at risk, including through collisions *(96)*.
- Pedestrians are not seen as equal members and users of road networks. Many cities and countries still see roads as the domain of motorized vehicles, with the widespread belief that pedestrians should not be on them. The inclusion of motorists' waiting time in economic modelling for traffic policy (and specific decisions such as signal phasing at crossings), alongside the absence of consideration of pedestrian waiting time at crossings, is direct proof of the lack of consideration *(56)*. As a result, traffic policy in many high-income countries is influenced by the astonishing discrepancy that a person's time sitting in a car has economic worth, but the same person's time waiting to cross the road has none.
- Victim blaming has long been acknowledged as a concern in road safety *(97,98)*, particularly for pedestrians *(56)*. If there are no uninvolved witnesses, police have an onerous responsibility when responding to fatal or serious injury pedestrian crashes. The pedestrian is frequently killed or gravely injured, rendering them unable to provide an account of events, but the motorist is likely to be unharmed and able to provide their statement. Once the pedestrian is perceived as primarily at fault, there is a tendency to advocate for what pedestrians should do differently to avoid injury in the future.
- The benefits of passive safety in vehicles mostly accrue to vehicle occupants rather than pedestrians. Improved safety for car occupants has resulted from stronger regulation and market factors whereas the safety gain for pedestrians has been significantly smaller. Despite the fact that vehicle designs that lower pedestrian danger in the case of a crash exist (and have been perfected over many years *(99)*), only a few countries have implemented regulations on vehicle pedestrian protection.
- The advantages of an antilock brake system (ABS) are dependent on detection, and pedestrian detection may be ineffective. Autonomous braking has the potential to prevent numerous deaths and injuries. However, the detection methods on which benefits are based frequently miss pedestrians, resulting in an overestimation of pedestrian benefits claimed by supporters *(100)*.
- The proliferation of four-wheel drive (4WD) and sport utility vehicles (SUVs) is detrimental to pedestrian safety. 4WD vehicles – which are now more common than SUVs in the United States, Australia and other countries – have high fronts that injure pedestrians more severely in the event of a collision.

As a result, the increase in these vehicles is a major contributor to the lack of progress in pedestrian safety *(10,101,102).*

- The number of pedestrians killed or injured is grossly underestimated, leaving decision-makers unaware of the true scale of the pedestrian safety issue The substantial differences between official statistics compared with both WHO estimates and Global Burden of Disease mortality estimates suggest that underreporting of deaths and injuries is widespread in many LMICs. Pedestrian crash underreporting is a long-standing issue *(103)*, which has yet to be resolved. Underreporting of crashes is consistently biased by crash type, with crashes involving vulnerable road users, such as pedestrians, being less likely to be reported than other crashes of comparable severity *(104)*.

3.4 Evaluating progress and using results for improvement

Evaluation is a critical component of pedestrian safety interventions. A thorough evaluation, properly implemented, measures the effectiveness of the programme and assesses whether the desired outcomes are being achieved. It can enable the identification of success as well as constraints and provide insights on how to adjust programmes so that targets are achieved. The results of evaluation are key inputs for decision-makers involved in pedestrian safety programmes. They also provide the content for dissemination and improvement of ideas and initiatives, and contribute to international learning.

There may be some variation in the specific ways different agencies plan, choose evaluation methods and disseminate results, but the basic principles to bear in mind on evaluation of pedestrian safety programmes remain the same *(2)*:

- **Plan the evaluation:** Ensure that monitoring and evaluation (M&E) are included in any pedestrian safety plan, strategy or intervention at national or local level. It is better to plan for evaluation from the beginning rather than doing so once implementation has begun. Determining the aims of evaluation, type of evaluation and indicators to adopt during the planning phase of a programme will ultimately improve the quality of the evaluation.
- **Identify existing M&E activities in your setting and the responsible agencies:** This exercise helps to identify relevant existing data and can develop partnerships with existing agencies in M&E. Collect baseline data using surveys and existing databases if they exist.
- **Identify suitable indicators to monitor processes, outputs and outcomes.** Table 3.1 lists three main categories of indicators for M&E of pedestrian safety programmes.
- **Conduct the evaluation consistently, as planned:** Once the appropriate evaluation design and methods have been specified – with respect to the unit of analysis, population, sample and methods of data collection and analysis – conduct the evaluation according to those methods.
- **Disseminate evaluation results:** Use evaluation results to improve the programme and inform the public and other stakeholders about successes or failures. The results of the evaluation need to be disseminated, discussed and used by programme staff, government, the public and sponsors of pedestrian safety initiatives. These different groups need to consider what the programme can do better and what it can avoid in order to improve pedestrian safety in a given setting.

Table 3.1 Indicators for evaluating pedestrian safety programmes

Type of indicator	Purpose	Examples
Process	To assess progress in the process of change, in order to show how the programme or activity has been implemented or executed	• Setting up a working group • Conducting a situational assessment • Preparing a pedestrian safety plan • Prioritizing pedestrian safety in national and local policies and programmes • Implementing a plan of action
Output	To measure outputs or products that are attributable to the programme processes	• Publishing and disseminating a pedestrian safety plan • Officially launching a pedestrian safety plan • Endorsement of a pedestrian safety plan by national or local government • Allocating human and financial resources to a pedestrian safety plan • Securing space for pavements
Outcome	To measure the ultimate outcomes of implementing various activities	• Increase in knowledge and awareness about risk factors for pedestrian injury • Change in behaviour: speed, drinking and driving, street crossing and yielding at pedestrian priority points • Reduction in pedestrian fatalities and injuries

Current pedestrian safety evaluation methods that can be used to measure pedestrian safety include:

- Pedestrian Safety Evaluation Program (Ottawa, Canada) *(105).*
- Pedestrian safety index for evaluating street facilities in urban areas *(106).*
- Urban Road Safety Audit Toolkit *(107).*
- Public Transport Access Audit Toolkit *(108).*
- America Walks Pedestrian Advocacy Toolkit *(109).*
- Geometric design strategies for improving pedestrian safety and accessibility at signalized intersections *(110).*

Various study designs are recommended for effective evaluations, such as "before-and-after" studies, randomized controlled trials, case-control studies and case-crossover studies *(111–116).* All require adequate data – and if impact is measured in terms of change in fatal crashes or injury crashes, at least 3 years' worth of data should be used to measure the intervention's impact.

3.5 Summary

Improving road safety in general, and pedestrian safety specifically, involves a continuous cycle of planning, implementation and evaluation, and is never a one-off undertaking. This process requires a comprehensive understanding of the risk factors involved in different settings, the nature of the problem, relevant stakeholders and what is already in place. Implementation of such interventions should take a comprehensive approach and be related to effective measures on speed management, road transport infrastructure, vehicle design, enforcement and education, and post-crash care. The continued implementation of pedestrian safety interventions will enable decision-makers and practitioners to leverage opportunities as well as address unexpected challenges that need to be managed as this cycle moves on.

There are several challenges to confront, such as the general neglect of pedestrians in overall road transport infrastructure planning and implementation.

Evaluation is a critical component of pedestrian safety interventions. A thorough evaluation, properly implemented, measures programme effectiveness and assesses whether the desired outcomes are being achieved. A scientific, evidence-based evaluation is important for gauging the impact of a given intervention. Various study designs are recommended for an effective evaluation such as before-and-after studies, randomized controlled trials, case-control studies and case-cross over studies. All require adequate data.

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