CHAPTER 4

Interventions

A road traffic system designed for safe, sustainable use

Road traffic deaths and serious injuries are to a great extent preventable, since the risk of incurring injury in a crash is largely predictable and many countermeasures, proven to be effective, exist. Road traffic injury needs to be considered alongside heart disease, cancer and stroke as a preventable public health problem that responds well to targeted interventions (*1*).

The provision of safe, sustainable and affordable means of travel is a key objective in the planning and design of road traffic systems. To achieve it requires firm political will, and an integrated approach involving close collaboration of many sectors, in which the health sector plays a full and active role. In such a systems-based approach, it is possible at the same time to tackle other major problems associated with road traffic, such as congestion, noise emission, air pollution and lack of physical exercise (*2*).

Progress is being made in many parts of the world where multisectoral strategic plans are leading to incremental reductions in the number of road deaths and injuries (*3, 4*). Such strategies address the three prime elements of the traffic system – vehicles, road users and the road infrastructure. Vehicle and road engineering measures need to take into account the safety needs and physical limitations of road users. Vehicle technology needs to consider roadside equipment. Measures involving the road infrastructure must be compatible with the characteristics of vehicles. Vehicle measures should be complemented by appropriate behaviour on the part of road users, such as wearing seat-belts. In all these strategies, managing speed is a fundamental factor.

This chapter provides an overview of the wide range of interventions for road safety, examining what is known about their practicability, effectiveness, cost and acceptability to the public. Proven interventions in one setting, of course, may not easily be transferable elsewhere, but will instead require careful adaptation and evaluation. Where effective interventions are altogether lacking, scientific research is needed to develop and test new measures.

Managing exposure to risk through transport and land-use policies

Perhaps the least used of all road safety intervention strategies are those that aim to reduce exposure to risk. Yet the underlying factors determining exposure to risk can have important effects (*5*). While further research is required to fully explore intervention strategies, it is known that exposure to road injury risk can be decreased by strategies that include:

- — reducing the volume of motor vehicle traffic by means of better land use;
- — providing efficient networks where the shortest or quickest routes coincide with the safest routes;
- — encouraging people to switch from higher-risk to lower-risk modes of transport;
- — placing restrictions on motor vehicle users, on vehicles, or on the road infrastructure.

The impact of strategies aimed at influencing mobility and access tends to be cumulative and mutually reinforcing, and such strategies can most effectively be implemented in combination. In high-income countries, it has been estimated that a comprehensive programme with a complementary set of cost-effective measures could reduce the total amount of car travel, per capita, by 20–40% (*6*). Many countries are now addressing these issues, mainly in the interests of sustainable mobility. Bogotá in Colombia, for instance, has attempted to reduce exposure to risk through measures that include a mass transit programme for vulnerable road users and restrictions on motor vehicle access to the city during certain times (*7, 8*).

Reducing motor vehicle traffic

Efficient land use

The organization of land use affects the number of trips people make, by what means they choose to travel, the length of trips and the route taken (*9*). Different land use creates different sets of traffic patterns (*10*). The main aspects of land use that influence road safety are (*9*):

- — the spatial distribution of origins and destinations of road journeys;

- urban population density and patterns of urban growth;
- the configuration of the road network;
- the size of residential areas;
- alternatives to private motorized transport.

Land-use planning practices and "smart growth" land-use policies – development of high-density, compact buildings with easily accessible services and amenities – can serve to lessen the exposure risk of road users. The creation of clustered, mixed-use community services, for example, can cut the distances between commonly used destinations, curtailing the need to travel and reducing dependence on private motor vehicles (*6*).

Safety impact assessments of transport and land-use plans

Evaluations of the impact on safety of transport projects usually focus on the individual project, with little consideration of the effect on the wider network (*11*). This can result in strategies for improving mobility, reducing congestion and improving the environment that are incompatible with road safety. The likely effects of planning decisions to do with transport or land use on the *whole* of the road network should therefore be considered at an early stage, to avoid unintended, adverse consequences for road safety (*9, 10, 12*).

Area-wide safety impact assessments should be routinely conducted at the same time as other assessments of policies and projects related to transport and land use. Safety impact assessments are not yet carried out either routinely or systematically in most places, though there has been experience with them in the Netherlands, and to some extent elsewhere (*13*).

Providing shorter, safer routes

In an efficient road network, exposure to crash risk can be minimized by ensuring that trips are short and routes direct, and that the quickest routes are also the safest routes. Route management techniques can achieve these objectives by decreasing travel times on desired routes, increasing travel times on undesired routes, and re-directing traffic (*14*). Having to take a detour in a car means that extra fuel will be used, but for pedestrians it means extra physical exertion. There is thus a strong incentive to find the easiest and most direct route. Studies have, in fact, shown that pedestrians and cyclists place a higher value on journey time than do drivers or those using public transport – a finding that should be reflected in planning decisions (*15, 16*).

Safe crossing facilities for pedestrians and cyclists are likely not to be used if many steps need to be climbed, if long detours are involved, or if the crossings are poorly lit or underpasses badly maintained. A study in Brazil showed that many pedestrians who had been struck by vehicles had chosen to climb over central traffic-lane barriers, rather than climb a flight of stairs to a footbridge (*17*). Interviews with pedestrian crash survivors in Mexico found that one of the main underlying risk factors was the presence of bridges that were poorly located or regarded as unsafe (*18*). In Uganda, the construction of an overpass for pedestrians on a major highway in Kampala had little effect either on pedestrian road behaviour or on the incidence of crashes and injuries because of its inappropriate location (*19*).

Trip reduction measures

It has been estimated from studies in high-income countries that, under certain conditions, for each 1% reduction in motor vehicle distance travelled, there is a corresponding 1.4–1.8% reduction in the incidence of crashes (*20, 21*). Measures that may reduce the distance travelled include:

- making greater use of electronic means of communications as a substitute for delivering communications by road;
- encouraging more people to work from home, using e-mail to communicate with their workplace;
- better management of commuter transport, and of transport to and from schools and colleges;
- better management of tourist transport;
- bans on freight transport;
- restrictions on vehicle parking and road use.

Encouraging use of safer modes of travel

Whether measured by the time spent travelling or by the number of trips, travel by bus and train is many times safer than any other mode of road travel. Policies that stimulate the use of public transport, and its combination with walking and cycling, are thus to be encouraged. While the walking and cycling parts of journeys bear relatively high risks, pedestrians and cyclists create less risk for other road users than do motor vehicles (*6*). However, by implementing known safety measures, it should be possible to achieve a growth in healthier forms of travel, such as walking and cycling, and at the same time reduce the incidence of deaths and injuries among pedestrians and cyclists. These are goals that are increasingly being adopted in national transport policies in high-income countries (*15*).

Strategies that may increase the use of public transport include (*6*):

— improved mass transit systems (including improvements to routes covered and ticketing procedures, shorter distances between stops, and greater comfort and safety of both the vehicle and the waiting areas);
— better coordination between different modes of travel (including the coordination of schedules and the harmonization of tariff schemes);
— secure shelters for bicycles;
— allowing bicycles to be carried on board trains, ferries and buses;
— "park and ride" facilities, where users can park their cars near public transport stops;
— improvements to taxi services;
— higher fuel taxes and other pricing reforms that discourage private car use in favour of public transport.

Financial incentives have proved successful in some highly-motorized countries; for example, in the Netherlands, a free public transport pass for students has resulted in lower car use (*22*).

In many low-income countries, however, public transport services often operate without regulation and create unacceptable levels of risk, both for their occupants and for those outside the vehicle. These risks arise from overloaded vehicles, long working hours of drivers, speeding and other dangerous behaviour. All the same, an improved public transport system with proper regulation and enforcement, combined with non-motorized transportation – cycling and walking – can play an important part in low-income and middle-income countries as a response to the growing demand for transport and accessibility.

Despite the generally lower injury risks associated with public transport, more research on the effectiveness of public transport strategies in reducing the incidence of road traffic injuries still needs to be carried out.

Minimizing exposure to high-risk scenarios

Restricting access to different parts of the road network

Preventing pedestrians and cyclists from accessing motorways and preventing motor vehicles from entering pedestrian zones are two well-established measures for minimizing contact between high-speed traffic and unprotected road users. Because vehicles are physically prevented from entering them, pedestrian zones are safer for travel on foot and also – where there is shared use – for bicycle travel. Motorways have the lowest crash rates, in terms of distance travelled, of the whole road network, by virtue of their sole use by motor vehicles, and their use of clear separation of traffic and segregated junctions.

Giving priority in the road network to higher occupancy vehicles

Giving vehicles with many occupants priority in traffic over those with few occupants is a means of reducing the overall distance travelled by private motorized transport – and hence of cutting down on exposure to risk. This strategy is adopted by many cities worldwide. For example, the high-capacity bus system in the city of Curitibá, Brazil, provides segregated bus lanes, priority at traffic lights for buses, as well as safe and fast access for users (*23*).

Restrictions on speed and engine performance of motorized two-wheelers

Many high-income countries have introduced regulations relating to speed and engine performance for mopeds and motorcycles, with the aim of reducing rates of crashes and injury (*24*).

Restricting the engine capacity for beginner motorcyclists has proved to be a successful intervention. In the United Kingdom in the early 1980s, for instance, the maximum engine size of a motorcycle that learners could ride was reduced from 250 cc to 125 cc; this was accompanied by a limitation on the maximum power output (to 9 kW). As a result, many inexperienced motorcyclists transferred to less powerful vehicles, leading to an estimated 25% reduction in casualties among young motorcyclists (*25*). A later study found a significantly greater crash risk associated with larger motorcycles, despite the fact that these machines were ridden mostly by more experienced riders (*25*).

Japan is one country that imposes limits, for safety reasons, on the engine size and performance of large motorcycles used domestically, though similar controls do not apply to exports of new motorcycles from Japan to other countries (*26*). In the case of these exported motorcycles, outputs of 75–90 brake horse power (56–67 kW) – or even 130 brake horse power (97 kW) – are quite common now, with top speeds reaching almost 200 miles/h (322 km/h) (*27*).

Increasing the legal age for use of motorized two-wheelers

In Malaysia, out of a number of proposed measures to reduce motorcycle crashes, increasing the legal riding age from 16 to 18 years was found to have the greatest cost–benefit. Preventing young riders from riding at night was also considered. Although this measure also produced a positive net benefit, the magnitude of the saving was small, since most crashes occurred during daytime (*28*).

Graduated driver licensing systems

The high risks faced by young drivers and motorized two-wheeler riders in their first months of driving have already been discussed (see Chapter 3). For young car drivers, the two principal risks are night-time driving and transporting young passengers (*29*). In response, graduated driver licensing systems were first introduced in New Zealand in 1987, and are now widely implemented in Canada, the United States and some other places. These schemes provide gradual access to a full driving licence for novice drivers and riders (*30*) (see Box 4.1).

BOX 4.1

Graduated driver licensing systems

Beginner drivers of all ages lack both driving skills and experience in recognizing potential dangers. For newly-licensed teenage drivers, their immaturity and limited driving experience result in disproportionately high rates of crashes. Graduated driver licensing systems address the high risks faced by new drivers by requiring an apprenticeship of planned and supervised practice – the learner's permit stage. This is then followed by a provisional licence that places temporary restrictions on unsupervised driving (*31*). Commonly imposed restrictions include limits on night-time driving, limits on the number of passengers, and a prohibition against driving after drinking any alcohol. These restrictions are lifted as new drivers gain experience and teenage drivers mature, gaining a full licence (*32*). Although the specific requirements for advancing through these three stages – the learner's permit, the provisional licence and the full licence – vary according to country, they provide a protective environment while new drivers become more experienced (*33*).

Graduated driver licensing schemes have consistently proved effective in reducing crash risks for new drivers. Peer-reviewed evaluations of the effectiveness of such schemes in Canada, New Zealand and the United States have reported reductions in crashes involving new drivers in the range of 9–43% (*34–36*). Why such reductions should exist has not yet been definitively established. It is generally accepted, though, that the safety benefits of schemes result both from decreases in the amount of driving by inexperienced drivers and from improvements in their driving skills under conditions of low risk.

The elevated risk of a crash for beginner drivers is universal, and graduated driver licensing can effectively reduce this risk. It can apply to all newly-licensed drivers, not just those who are young. Research has clearly demonstrated that older beginner drivers experience higher crash rates than drivers of the same age with several years of experience. For this reason, Canada, where many new drivers are not young, applies graduated driver licensing to all beginners, regardless of their age. Even countries where the legal age for driving is higher than the average can benefit from the introduction of graduated driver licensing.

The reduction in the incidence of crashes resulting from the introduction of these systems varies from 4% to over 60%. This large range may in part be explained by methodological differences, differences in the restrictions used and the degree to which they are enforced (*35*). The major reductions would seem to arise from more supervised driving and from a high degree of compliance with restrictions (*37*). It is not as yet clear, though, which of the many restrictions – including limits on the number of passengers carried, use of seat-belts, lower blood alcohol concentration (BAC) limits and night-time driving bans – is the most cost-effective (*35*). Graduated driver licensing schemes have generally been well accepted (*29*).

The New Zealand scheme is made up of three stages, and all new drivers aged 15–24 years have to take part. The first stage is a six-month supervised learner driver permit, which is obtained by passing a written test, an oral theory test and an eyesight test. The restricted licence stage lasts for 18 months and is completed by passing a practical driving test. There are bans during both the first two stages on night-time driving (from 22:00 to 05:00) and on carrying passengers under the age of 20 years (unless the driving is supervised), as well as a BAC limit of 0.03 g/dl. Violations of these conditions can result in the licence restrictions being extended by a further six months. An evaluation of the scheme found that it had led to an 8% reduction in crashes involving serious injury, and that the restrictions, particularly the night-time driving ban, had made a significant contribution (*36*).

Another version of a graduated licensing system, introduced in Austria in 1993, resulted in the incidence of crashes being reduced by more than a third (*22*). There was a probation period of two years for novice drivers and a BAC limit of 0.01 g/dl. If, during this period, there were any offences involving excess alcohol or driving that led to injury or death, a two-year extended probation was imposed, as well as obligatory attendance at a driver improvement programme.

Shaping the road network for road injury prevention

Road safety considerations are central to the planning, design and operation of the road network. By adjusting the design of the road and road networks to accommodate human characteristics and to be more "forgiving" if an error is made, road safety engineering strategies can make a major contribution to road injury prevention and mitigation (*10*).

Safety-awareness in planning road networks

The framework for the systemic management of road safety in high-income countries is increasingly defined by the following activities (*10, 38–40*):

- classifying the road network according to their primary road functions;
- setting appropriate speed limits according to those road functions;
- improving road layout and design to encourage better use.

These approaches can, in principle, be adapted to the contexts of middle-income and low-income countries. Within these general principles, safety engineering and traffic management should aim:

- to prevent road use that does not match the functions for which the road was designed;
- to manage the traffic mix by separating different kinds of road users, so as to eliminate conflicting movements of road users, except at low speeds;
- to prevent uncertainty among road users about appropriate road use.

A large body of knowledge exists to support the use of a safety-awareness approach to road planning and is available in the form of design standards and best practice guidelines and manuals. Examples include the requirements for the development of "sustainable safety" in road networks in the Netherlands (*41*) and an earlier set of guidelines for achieving safer roads in developing countries (*10*).

Classifying roads and setting speed limits by their function

Many roads have a range of functions, and are used by different types of vehicles and by pedestrians – with large differences in speed, mass of vehicle and degree of protection. In residential areas and on urban roads this often leads to conflicts between the mobility of motor vehicle users on the one hand and the safety of pedestrians and cyclists on the other. Most pedestrian crashes occur within one mile (1.6 km) of the victim's home or place of business (*15, 42*).

Classifying roads functionally – in the form of a "road hierarchy", as it is known in highway engineering – is important for providing safer routes and safer designs. Such a classification takes account of land use, location of crash sites, vehicle and pedestrian flows, and objectives such as speed control.

The Dutch "sustainable safety" policy sets different speed limits according to the road function (see Box 4.2), together with a range of operational requirements (*41*). A study found that, by adopting these principles, a reduction of more than one third in the average number of injury crashes per million vehicle-kilometres – driven on all types of roads in the Netherlands – could be achieved (*43*).

Research is needed so that these principles can be adopted more widely, and particularly to work out how to adapt and apply them in the specific contexts of low-income countries.

Incorporating safety features into road design

A key objective of safety engineering is to make drivers naturally choose to comply with the speed limit. Through the use of self-explanatory road layouts, engineering can lead to safer road user behaviour, as well as correcting defects in road design that otherwise may lead to crashes. The following description of different types of roads illustrates the relationship between road function, road speed and road design.

Higher-speed roads

Higher-speed roads include motorways, expressways and multi-lane, divided highways with limited access. They are designed to allow for higher speeds by providing large-radius horizontal and vertical curves, "forgiving" roadsides, entry and exit "grade-separated" junctions – where there is no contact between motorized and non-motorized traffic – and median barriers to separate opposing directions of traffic. Such roads have the lowest rates of road injury in terms of distance travelled because of these design features and the fact that non-motorized users are prohibited (*39*). In low-income countries, it is also necessary to separate motorized two-wheelers from car and truck traffic travelling in the same direction.

BOX 4.2

Road types and appropriate speeds

The Dutch policy of sustainable safety divides roads into one of three types according to their function, and then sets speed limits accordingly (*41*):

- **Flow roads** (or through-roads). For such roads, through-traffic goes from the place of departure to the destination without interruption. Speeds above 100–120 km/h are not permitted, and there is a complete separation of traffic streams.
- **Distributor roads**. These roads enable users to enter or leave an area. The needs of moving traffic continue to be predominant. Local distributor roads carry traffic to and from large urban districts, villages and rural areas, and have traffic interchanges at limited sections. These roads give equal importance to motorized and non-motorized local traffic, but separate users wherever possible. Speeds on distributor roads should not exceed 50 km/h within built-up areas or 80 km/h outside such areas. There should be separate paths for pedestrians and cyclists, dual carriageways with separation of streams along the full length, speed controls at major crossings, and right of way.
- **Residential access roads**. These roads are typically used to reach a dwelling, shop or business. The needs of non-motorized users are predominant. There is a constant access and interchange of traffic and the vast majority of roads are of this type. For residential access roads in towns and villages, speeds above 30 km/h are not permitted. In rural areas, no speeds over 40 km/h are allowed at crossings and entries – otherwise 60 km/h may be acceptable.

Where a road performs a mixture of functions, the appropriate speed is normally the lowest of the speeds appropriate to the individual functions.

Single-lane carriageways

Single-lane carriageways in rural areas include many different types of road. The numbers and rates of casualties are much higher than on motorways, because of the large differences in speed between the various types of user. Crashes on local rural roads arise most commonly from vehicles leaving the road through loss of control as a result of inappropriate speed (*44*). Apart from speed limits, a range of engineering measures is needed to encourage appropriate speed and make hazards easily perceptible. These measures include:

- provision for slow-moving traffic and for vulnerable road users;
- lanes for overtaking, as well as lanes for vehicles waiting to turn across the path of oncoming traffic;
- median barriers to prevent overtaking and to eliminate head-on crashes;
- better highlighting of hazards through road lighting at junctions and roundabouts;
- improved vertical alignment;
- advisory speed limits at sharp bends;
- regular speed-limit signs;
- rumble strips;
- the systematic removal of roadside hazards – such as trees, utility poles and other solid objects.

Much best practice in this area has been identified in high-income countries (*45*).

A particular speed management problem is how to handle the transition from high-speed roads to lower-speed roads – for instance, when a vehicle leaves a motorway, or when it enters a winding stretch of narrow road after a long, straight stretch of road. The creation of transition zones on busy roads approaching towns and villages can reduce crashes and injuries for all types of road user. Design features that use a "gateway", or threshold, can influence drivers progressively to reduce their speed, and signal the beginning of the speed limit for commercial and residential areas. In approaches to slower-speed zones, rumble strips, speed humps, visual warnings in the pavement, and roundabouts have all been found useful in slowing the speed of vehicles (*45*). In Ghana, the introduction of rumble strips reduced crashes by some 35% and deaths by 55% in certain locations (*46*) (see Box 4.3).

BOX 4.3

Speed bumps in Ghana: a low-cost road safety intervention

Road safety is a serious problem in Ghana, where fatality rates are some 30 to 40 times greater than those in industrialized countries. The excessive vehicle speeds that prevail on the country's inter-urban highways and on roads in built-up areas have been shown to be a key contributory factor in serious traffic crashes (*46*).

In recent years, speed bumps have been installed at some crash-prone locations on the highways, so as to lower the speed of vehicles and improve the traffic environment for other road users, including pedestrians and cyclists, in built-up areas. These speed bumps produce discomfort when vehicles pass over them at higher speeds; with their vehicles lifted off the ground and with the resulting noise, drivers are forced to reduce their speed. This in turn decreases the kinetic energy of the vehicle that can cause injuries and deaths on impact, and gives drivers longer warning of possible collisions, lessening the likelihood of road crashes.

The use of speed bumps, in the form of rumble strips and speed humps, has been found to be effective on Ghanaian roads. For instance, rumble strips on the main Accra–Kumasi highway at the crash hot spot of Suhum Junction reduced the number of traffic crashes by around 35%. Fatalities fell by some 55% and serious injuries by 76%, between January 2000 and April 2001. This speed-reducing measure succeeded in reducing or even eliminating certain kinds of crashes as well as improving the safety of pedestrians (*46*).

Speed control bumps and humps have now become increasingly common on Ghanaian roads, particularly in built-up areas where excessive vehicle speeds threaten other road users. A wide range of materials – including vulcanized rubber, hot thermoplastic materials, bituminous mixes, concrete and bricks – have been used in the construction of the speed control areas.

Rumble strips are cheap and easy to install. They have been constructed at potentially dangerous places on the Cape Coast–Takoradi highway, the Bunso–Koforidua highway and the Tema–Akosombo highway. Speed humps, on the other hand, have been laid to slow down vehicles and improve the safety of pedestrians in the towns of Ejisu and Besease on the Accra–Kumasi highway.

Residential access roads

Residential access roads are often designed to achieve very low speeds. Speed limits, usually supported by physical self-enforcing measures to encourage compliance, are normally around 30 km/h, though lower limits are often prescribed.

Area-wide urban safety management

Engineering measures applied on an area-wide basis in towns and cities create safer conditions for pedestrians and cyclists, as well as avoiding the displacement of traffic which could lead to crashes elsewhere. Research is urgently needed in developing countries into area-wide urban safety management relating to motorized two-wheelers.

The principal road safety engineering techniques for improving the safety of pedestrians and cyclists are the provision of safer routes – through segregation and separation – and area-wide speed reduction or traffic-calming measures (*22, 23*). These are discussed below.

Safer routes for pedestrians and cyclists. The creation of networks of connected and convenient pedestrian and cyclist routes, together with the provision of public transport, can lead to greater safety for vulnerable road users (*47*). The routes will typically consist of footpaths or cycle paths separate from any carriageway, pedestrian-only areas with or without cyclists being admitted, footpaths or cycle tracks alongside carriageways, and carriageways or other surfaces shared with motor vehicles. Where pedestrian or cycle routes cross significant flows of motor vehicle traffic, the location and design of the crossing point needs special attention. Where routes are not separated from carriageways, or where space is shared with motor vehicles, the physical layout will need to manage speeds (*15*).

Pedestrian footpaths and pavements are used more in high-income than in low-income countries and tend to be in urban rather than rural areas. The risk of a crash on roads without pavements separating pedestrians from motorized traffic is twice that on a road with a pavement (*48*). Pavements in poor condition or obstructed by parked vehicles may force pedestrians to walk on the street, thus significantly increasing crash risk. This danger is particularly great for people carrying heavy loads, pushing prams, or who have difficulty in walking. Studies in low-income and middle-income countries have shown that even where pavements exist, they are often blocked – for instance, by street vendors' stalls (*18, 49*).

Providing pavements for pedestrians is a proven safety measure, which also helps the flow of motorized traffic. Bicycle paths have also been shown to be effective in reducing crashes, particularly at junctions (*22*). Danish studies have found reductions of 35% in cyclist casualties on particular routes, following the construction of cycle tracks or lanes alongside urban roads (*50*).

Traffic-calming measures. At speeds below 30 km/h pedestrians can coexist with motor vehicles in relative safety. Speed management and traffic-calming include techniques such as discouraging traffic from entering certain areas and installing physical speed-reducing measures, such as roundabouts, road narrowings, chicanes and road humps. These measures are often backed up by speed limits of 30 km/h, but they can be designed to achieve various levels of appropriate speed.

In Europe, there has been much experimentation with these measures and crash reductions of between 15% and 80% have been achieved (*44, 51–54*). In the town of Baden, Austria, about 75% of the road network is now part of a 30 km/h zone, or else a residential street with an even lower speed limit. Since integrated transport and a wide-ranging safety plan were introduced in 1988, the town has seen a 60% reduction in road casualties (*55*).

Most of the principles incorporated into design guidelines for traffic calming in high-income countries also apply to low-income countries, though in practice the guidelines will need to be modified because of the much higher proportion of non-motorized traffic (*23*). As Table 4.1, which summarizes the effects of measures undertaken in a British town, shows, area-wide speed and traffic

TABLE 4.1

Area-wide speed reduction – cost and benefits

	Town centre	Residential area
Number of road traffic injuries prevented/year	53	145
Saving-crash costs (£, 25 years, 5%[a])	33 350 000	91 260 000
Increased costs-travel time (£, 25 years, 5% [a])	21 900	53 250 000
Loss of consumers' surplus of travel [b] (£)	2 415 000	9 300 000
Total benefits (£)	9 035 000	28 710 000
Costs of implementing measures (£)	4 910 000	2 955 000
Cost–benefit	1:1.84	1:9.72

[a] 5% annual discount rate for discounting benefits to present values.

[b] Loss of benefits to consumers.

Source: reproduced from reference *56*, with minor editorial amendments, with the permission of the publisher.

management can be highly effective, particularly in residential areas, where benefits have been found to exceed costs by a factor of 9.7 (*56*).

A systematic review of 16 controlled studies from high-income countries also showed that area-wide traffic calming in urban areas could reduce road traffic injuries. No similar studies from low-income or middle-income countries were found (*57*).

Safety audits

When new transport projects are proposed, area-wide safety impact assessments are needed to ensure the proposals do not have an adverse safety impact on the surrounding network. Road safety audits are then required to check that the proposed design and implementation are consistent with safety principles, and to examine whether further design changes are needed to prevent crashes (*12*).

The safety audit procedure is usually carried out at various stages of a new project, including:

- the feasibility study of the project;
- the draft design;
- the detailed design;
- before the project becomes operational;
- a few months after the project is operational.

An essential element of the audit process is that it should be carried out separately by both an independent design team, and a team with experience and expertise in road safety engineering and crash investigation. Guidelines for safety audits have been developed in many parts of the world, including Malaysia (*58–60*).

Formal safety audit procedures have been shown to be effective and cost-effective ways of improving road safety and reducing the long-term costs associated with a new road scheme (*39*). Mandatory safety audit procedures have existed in a number of countries including Australia, Denmark, New Zealand and the United Kingdom for several years (*61*). In New Zealand, it has been estimated that the procedures carry a cost–benefit ratio of 1:20 (*62*). A Danish study assessed the value in cost–benefit terms of 13 schemes and found first year rates of return of well over 100% (*63*).

Crash-protective roadsides

Collisions between vehicles leaving the road and roadside objects including trees, poles and road signs, often of very high mass, are a major road safety problem worldwide. Research that built on work by the Organisation for Economic Co-operation and Development in 1975 (*64*) suggests that existing strategies to tackle the problem of roadside objects would be strengthened by (*65*):

- designing roads without dangerous roadside objects;
- introducing a clear zone at the side of the road;
- designing roadside objects so that they are more "forgiving";
- protecting roadside objects with barriers to absorb part of the impact energy;
- protecting vehicle occupants from the consequences of collisions with roadside objects, through better vehicle design.

Collapsible lighting columns and other devices that break away on impact were first introduced in the United States in the 1970s and are now used widely throughout the world. These objects are either mounted on shear bolts, or else are constructed of a deformable, yielding material. Slip-base poles break away at the base when struck by a vehicle and include special provisions to ensure electrical safety. Early research conducted in the United States indicated that break-away columns could result in reductions in injuries of around 30% (*66*).

Safety barriers are frequently used to separate traffic or to prevent it from leaving the road. They are designed to deflect or contain the striking vehicle while ensuring that the forces involved do not result in serious injury to occupants of the vehicle. If properly installed and in the appropriate places, safety barriers can be effective in reducing the incidence of crashes, their severity and their consequences (*67*). Crash research has highlighted the need for more effective linkages between vehicle protection standards and standards for safety barriers, which take into account the range of vehicles – from small cars to heavy trucks – that are likely to make use of them.

Guard fences and rails are situated at the edge of the carriageway to deflect or contain vehicles, or in the central reserve where their aim is to reduce crashes involving vehicles crossing into approaching traffic. The fences and rails can be rigid (made of concrete), semi-rigid (made from steel beams or box beams) or flexible (made from cable or wire). Cable barriers have been used cost-effectively in Denmark, Sweden, Switzerland and the United Kingdom (*65*). Central cable rails are being installed to an increasing degree in Sweden to prevent dangerous overtaking on single-carriageway roads. On two-lane roads with grade-separated crossings, the use of central cable rails has produced estimated reductions of 45–50% in fatal and serious casualties (*68*).

Crash cushions

Crash cushions are very effective in reducing the consequences of a crash by cushioning the vehicle before it strikes rigid roadside hazards, such as bridge piers, barrier terminals, light posts and sign supports. Evaluations in the United States of crash cushion installations have found a reduction in fatal and serious injuries at crash sites of up to 75% (*66*). In Birmingham, England, installing crash cushions resulted in a 40% reduction in injury crashes, and a reduction (from 67% to 14%) in the number of fatal and serious crashes at the treated sites (*69*).

Remedial action at high-risk crash sites

The systematic implementation of low-cost road and traffic engineering measures is a highly cost-effective method of creating safer patterns of road use and correcting faults in the planning and design of the roads that have led to traffic crashes. The use of road safety audits and safety impact assessments can prevent such faults from being introduced into new or modified roads (*12*).

Low-cost road and traffic engineering measures consist of physical measures taken specifically to enhance the safety of the road system. Ideally, they are cheap, can be implemented quickly, and are highly cost-effective (see Table 4.2). Examples include:

- physical changes to roads to make them safer (e.g. the introduction of skid-resistant surfacing);
- the installation of central refuges and islands;
- improved lighting, signs and markings;
- changes in the operation of junctions, for example, by installing small roundabouts, changing the signal control or improving signs and markings.

Such measures can be applied at:

- high-risk sites, for instance, a particular bend or junction;
- along a section of route where the risk is greater than average, though the measures are not necessarily concentrated at specific sites;
- over a whole neighbourhood.

Experience has shown that for high benefits to be achieved relative to costs, a systematic and multidisciplinary approach to identify sites, to implement low-cost road and traffic engineering measures, and to evaluate outcomes is required, as well as an efficient organizational framework (*71*).

TABLE 4.2

Some examples of low-cost road safety measures in Norway

Road safety measure	Mean cost (Norway Kroner)	Mean annual average daily traffic[a]	Cost–benefit ratio
Pedestrian bridge or underpass	5 990 000	8 765	1:2.5
Converting 3-leg junction to roundabout	5 790 000	9 094	1:1.6
Converting 4-leg junction to roundabout	4 160 000	10 432	1:2.2
Removal of roadside obstacles	310 000	20 133	1:19.3
Minor improvements (miscellaneous)	5 640 000	3 269	1:1.5
Guard rail along roadside	860 000	10 947	1:10.4
Median guard rail	1 880 000	42 753	1:10.3
Signing of hazardous curves	60 000	1 169	1:3.5
Road lighting	650 000	8 179	1:10.7
Upgrading marked pedestrian crossings	390 000	10 484	1:14.0

[a] The sum of all motor vehicles passing a point on the road in a single year, divided by 365; this value excludes pedestrians and cyclists.

Source: reproduced from reference *70*, with minor editorial amendments, with the permission of the author.

Providing visible, crash-protective, "smart" vehicles

Improving the visibility of vehicles

Daytime running lights for cars

The term, "daytime running lights" refers to the use of lights (whether multipurpose or specially designed) on the front of a vehicle while it is running during daylight hours, so as to increase its visibility. Some countries – including Austria, Canada, Hungary, the Nordic countries and some states in the United States – now require by law varying levels of use of daytime running lights (*16*). This may involve either drivers switching on their headlamps or the fitting of switches or special lamps on vehicles.

Two meta-analyses of the effects of daytime running lights on cars show that the measure contributes substantially to reducing road crashes. The first study, which examined daytime crashes involving more than one party, found a reduction in the number of crashes of around 13% with the use of daytime lights, and reduction of between 8% and 15% as a result of introducing mandatory laws on daytime use (*16*). The number of pedestrians and cyclists hit by cars was reduced by 15% and 10%, respectively. The second study found a reduction of slightly over 12% in daytime crashes involving more than one party, a 20% decrease in injured victims and a 25% reduction in deaths in such crashes (*72*). A study of data over four years from nine American states concluded that, on average, cars fitted with automatic daytime running lights were involved in 3.2% fewer multiple crashes than vehicles without (*73*). Following the introduction of daytime running lights and the enforcement of their use in Hungary, there has been a 13% reduction in the number of frontal crashes in daylight (*74*).

A cost–benefit analysis of providing automatic light switches on cars for daytime running lamps using standard low-beam headlights found that the benefits outweighed the costs by a factor of 4.4. The fitting of daytime running lights with special lamps with economical bulbs increased the cost–benefit to a factor of 6.4 (*75*). Motorized two-wheeler users have expressed concerns that daytime running lights on cars could reduce the visibility of motorcyclists. While there is no empirical evidence to indicate this is the case, researchers have suggested that if such an effect did exist, it would be offset by the benefit to motorcyclists of increased car visibility (*22, 72*). In the two meta-analyses cited above, use of car daytime running lamps led to a reduction in pedestrian and cyclist crashes (*16, 72*).

High-mounted stop lamps in cars

High-mounted stop lamps on cars have also been adopted as standard equipment in many countries. They have led to a reduction of between 15% and 50% in rear crashes and cost–benefit ratios of 1:4.1 in Norway and 1:8.9 in the United States (*16*).

Daytime running lights for motorized two-wheelers

The use of daytime running lights by motorized two-wheelers has been shown to reduce visibility-related crashes in several countries by between 10% and 15%. In a study of 14 states in the United States with motorcycle headlight-use laws, a 13% reduction in fatal daytime crashes was observed (*76*). In Singapore, a study conducted 14 months after the introduction of legislation requiring motorcyclists to switch on their headlamps found that fatal daytime crashes had reduced by 15% (*77*). In Malaysia, where legislation requiring daytime use was preceded by a two-month information campaign, the number of visibility-related crashes fell by 29% (*78*). In Europe, motorcyclists who use daytime running lights have a crash rate that is about 10% lower than that of motorcyclists who do not (*22*).

One estimate of the cost–benefit ratio of using running lights in daytime is put at around 1:5.4 for mopeds and 1:7.2 for motorcycles (*16*).

Improving the visibility of non-motorized vehicles

The main intervention for pedestrians to protect themselves is to wear clothing that increases their visibility, especially in poor daylight and in darkness. For cyclists, front, rear and wheel reflectors, and bicycle lamps that are visible at specified distances, are often required in high-income countries. The quality and use of lights can be improved by enabling the storage of separate light systems or by designing the lighting into the cycle frame (*15*).

Safety researchers in low-income countries have suggested various means for improving the visibility of vulnerable road users. The use of retro-reflective vests, common in high-income countries, may be problematic owing to their cost and the discomfort in wearing them in hot climates. A design for a brightly-coloured orange or yellow shopping bag that can quickly be transformed into a conspicuous vest has been proposed for two-wheeler users in low-income countries (*79*). Encouraging the use of colours such as orange and yellow for bicycles, for wheels, and for the rear ends of rickshaws and other non-motorized vehicles, has also been suggested (*23*).

Many countries require the fitting of reflectors on the front and rear of non-motorized vehicles. In low-income countries, though, rules could be extended to cover all animal carts, cycle trishaws and other forms of local transport that currently create road safety risks because of their poor visibility at night. The use of reflectors on the sides of vehicles may be helpful at junctions (*23*). However, while all these aids to visibility would appear to have great potential, their actual effectiveness in increasing the safety of pedestrians and cyclists remains largely unknown and requires additional study (*80*).

Crash-protective vehicle design

While market forces can help advance in-car safety in individual car models, the aim of harmonizing legislative standards of vehicle design is to ensure a uniform and acceptable level of safety across a whole product line.

Legislative standards are produced by different authorities, from the national to international level. On a global scale, these include the United Nations Economic Commission for Europe, and on a regional level, groupings such as the European Union. Standardization at the regional and national levels, taking into account as it does local conditions, can often produce faster action than a similar process at the international level. High-income countries routinely set out their national priorities in reports to the International Technical Conferences on the Enhanced Safety of Vehicles. Priorities in some low-income and middle-income countries have also been identified (*23, 81–83*).

A study in the United Kingdom concluded that improved vehicle crash protection (also known as "secondary safety" or "passive safety") for car occupants and pedestrians would have the greatest effect, out of all new policies under consideration, in reducing road casualties in Great Britain (see Table 4.3) (*84*). Comparable analyses in New Zealand estimated that improvements being made in the safety of the vehicle fleet would reduce projected social costs in 2010 by just under 16% (*85*).

TABLE 4.3

Estimated serious and fatal road casualty reduction effects of new policies, averaged over all types of roads, for different road users, United Kingdom (expressed a percentage reduction in the number of road casualties)

Policy	Car occupants	Pedestrians	Cyclists	Motorcyclists	Others	All users
New road safety engineering programme	6.0	13.7	4.3	6.0	6.0	7.7
Improved vehicle crash protection (passive safety)	10.0	15.0	—	—	—	8.6
Other vehicle safety improvements	5.4	2.0	3.2	8.0	3.0	4.6
Motorcycle and bicycle helmets	—	—	6.0	7.0	—	1.4
Improving safety of rural single carriageways	4.1	—	—	4.2	4.1	3.4
Reducing crash involvement of novice drivers	2.8	1.3	1.0	0.8	0.4	1.9
Additional measures for pedestrians and cyclist protection	—	6.0	4.0	—	—	1.2
Additional measures for speed reduction	5.0	5.0	5.0	5.0	5.0	5.0
Additional measures for child protection	—	6.9	0.6	—	—	1.7
Reducing casualties in drink-drive accidents	1.9	0.4	0.2	0.8	0.5	1.2
Reducing crashes during high-mileage work driving	2.1	0.9	1.2	1.9	1.9	1.9
Additional measures for improved driver behaviour	1.0	1.0	1.0	1.0	1.0	1.0
Combined effect of all measures	33	42	24	30	19	35

Source: reproduced from reference *84*, with minor editorial amendments, with the permission of the publisher.

The concept of "crashworthiness" in vehicle design is now well understood and is incorporated into current car design in highly-motorized countries. If it were adopted globally, it would contribute substantially to increased road safety (*82*) (see Box 4.4).

Safer car fronts to protect pedestrians and cyclists

The majority of fatally-injured pedestrians are hit by the fronts of cars. Creating safer car fronts is thus a key means of improving pedestrian safety (*26, 88, 89*).

Crash engineers have known for some time how crash-protection techniques can be used to reduce deaths and serious injuries to pedestrians struck by the fronts of cars (*90–93*). Since the late 1970s, studies have been conducted on how the shape, stiffness and speed of passenger cars influence the

BOX 4.4

Vehicle safety standards

Vehicle engineering for improved safety can be achieved by modifying a vehicle to help the driver avoid a crash, or in the event of a crash, protect both those inside and outside the car against injury.

Research indicates that vehicle crash protection is a most effective strategy for reducing death and serious injury in road crashes. A review of the effectiveness of casualty reduction measures in the United Kingdom between 1980 and 1996 found that the greatest contribution to reducing casualties was secondary safety or crash protection improvements to vehicles. These accounted for around 15% of the reduction, compared with 11% for drink-drive measures and 6.5% for road safety engineering measures (*84*).

Another review, by the European Transport Safety Council, estimated that improved standards for crash protection could reduce deaths and serious injuries on European roads by as much as 20% (*86*). Analysis has shown that if all cars were designed to provide impact protection equivalent to that of the best cars in the same class, half of all fatal and disabling injuries could be avoided (*87*).

During the 1990s, significant steps towards improved protection of occupants of cars were made in the highly-motorized countries. In the European Union, there were several directives on frontal and side impact protection, and information on crash tests from the European New Car Assessment Programme (EuroNCAP) was widely disseminated. Much of the research and development necessary for improvements in other safety areas for car occupants – such as smart seat-belt reminders – has been completed and now requires legislation to bring it into force.

Globally, the predominant category of road casualties up to 2020 will continue to be vulnerable road users. Protection for those outside the vehicle against impact is thus a priority in the field of vehicle design.

resulting injuries of pedestrians and pedal cyclists. While the fitting of rigid, "aggressive" bull-bars has been much publicized as a cause for concern, research shows that it is, in fact, the ordinary car front that presents by far the greatest risk to pedestrians and cyclists in a frontal impact (*93–95*).

Performance requirements and test procedures have been devised by a consortium established by European governments – the European Enhanced Vehicle-safety Committee (EEVC). Between 1988 and 1994, an EEVC working group on pedestrian protection developed a complete series of test methods to evaluate the front of passenger cars with respect to pedestrian safety (*92*), and these test methods were further improved in 1998 (*95*). The tests assume an impact speed of 40 km/h and consist of the following:

- a bumper test to prevent serious knee-joint injuries and leg fractures;
- a bonnet leading-edge test to prevent femur and hip fractures in adults and head injuries in children;
- two tests involving the bonnet top to prevent life-threatening head injuries.

It has been estimated that take up of these tests could avoid 20% of deaths and serious injuries to pedestrians and cyclists in European Union countries annually (*87, 94, 96*).

These tests, with minor amendments have been used by the European New Car Assessment Programme since 1997, and more recently by the Australian New Car Assessment Programme. Of the many new cars tested to date, only one type of car has shown evidence of having reasonable protection – about 80% of the protection demanded by the tests at an estimated additional manufacturing cost for new designs of €10 per car (*97*). Studies carried out by national road safety research organizations in Europe have shown that the benefits of adopting the four EEVC tests would outweigh the costs (*98*).

Legislation in this area is expected shortly in several countries, but the contents of the legislation are the subject of continuing international discussions (*87, 99*). Experts believe that the adoption of the well-researched EEVC tests would save many lives (*82, 93, 100*) – perhaps as many as 2000 lives annually in the European Union alone (*87*).

Safer bus and truck fronts

Extending the crash-protective vehicle exterior concept to vans, pick-up trucks and other trucks, and buses is an urgent requirement for protecting vulnerable road users in low-income countries (*82, 88, 101*). Buses and trucks are involved in a greater proportion of crashes in low-income countries than they are in high-income countries (*102*). Preliminary investigations have suggested that significant reductions in injuries could be achieved if the geometry and design of truck fronts were changed (*102*). The critical geometric features that influence injury and that continue to require attention by truck designers have been set out (*101*). Given the growth of megacities such as Bangkok, Beijing, Mexico City, São Paulo, Shanghai and others, the protection of vulnerable road users from bus and truck fronts take on particular importance. Many such cities have unique vehicles, such as the *tuk-tuk* of Bangkok, the *becak* of Jakarta and the three-wheeled taxis of India. Such vehicles incorporate almost no concept of crash protection, for either pedestrians or occupants. They present a good opportunity, therefore, for technical knowledge to improve their safety to be transferred from western car designers (*23*).

Car occupant protection

The essential aims in crash protection are:

- to maintain, through appropriate design, the integrity of the car's passenger compartment;
- to provide protection against elements that could cause injury in the car's interior;
- to ensure that vehicle occupants are appropriately restrained;
- to reduce the probability of an occupant being ejected;
- to prevent injury to other occupants (in a frontal crash, unbelted rear-seat occupants can cause injury to belted occupants seated in front of them);
- to improve the compatibility between vehicles of different mass (e.g. between car and

sports utility vehicle, car and car, car and bus or truck, car and motorized two-wheeler or bicycle).

Car crash protection standards currently address areas such as structural design, and the design and fitting of seat-belts, child restraints, air bags, anti-burst door latches, laminated glass windscreens, seats, and head restraints. Such standards offering a minimum, but high level of protection need to be adopted in all countries.

Frontal and side impact protection. The vast majority of car crashes in high-income countries are offset frontal crashes (where only one side of a vehicle's front end hits the other vehicle or object). In the United States, for example, 79% of injuries from frontal crashes occur as a result of offset frontal crashes (*81*). A recent priority for safety engineers working on frontal impact protection has been to improve the car structure so it can endure severe offset impacts with little or no intrusion of external objects. This allows space, in the event of a crash, for the seat-belts and air bags to slow down the occupants with the minimum risk of injury.

In most high-income countries, there are legislative performance requirements for cars to undergo a full-width frontal barrier test or an offset deformable barrier test. The former is acknowledged as an appropriate method for testing occupant restraint systems in frontal crashes. The latter, the offset deformable barrier test, is a more realistic simulation of what happens to a car's structure in a typical injury-producing frontal crash. The use of both tests is therefore important to ensure crash protection for car occupants (*83, 103*). Both tests are appropriate for more types of vehicle than they are currently used for.

Side impacts, while less frequent than frontal crashes, typically cause more severe injuries. In side impacts, it is difficult to prevent occupants on the side that is struck from coming into contact with the car's interior. Attempts at greater protection thus rely on managing the problem of intrusion, and providing padding and side air bags. During the 1990s, legislative standards were introduced in most high-income countries to offer better protection in side impacts. Following the experiences and evaluation of these requirements for frontal and side impact protection in Europe, various improvements have since been identified (*83, 104*).

As mentioned earlier, advanced crash tests, carried out for the benefit of consumer information by various New Car Assessment Programmes and by organizations such as the Insurance Institute for Highway Safety in the United States, play a vital role in promoting car design that provides good frontal and side impact protection.

Occupant restraints. The use of seat-belts continues to be the most important form of occupant restraint. Measures to increase their use – by means of legislation, information, enforcement and smart audible seat-belt reminders – are central to improving the safety of car occupants. When used, seat-belts have been found to reduce the risk of serious and fatal injury by between 40% and 65%. The fitting of anchorages and seat-belts are covered by various technical standards worldwide and in most countries these standards are mandatory for cars. However, there is anecdotal evidence that a half or more of all vehicles in low-income countries may lack functioning seat-belts (*17*).

Air bags are being increasingly provided in cars as an extra means of restraint, in addition to three-point seat-belts. They should be fitted universally to increase the protection of occupants involved in crashes. While driver and front-seat passenger air bags do not offer protection in all types of impact and do not diminish the risk of ejection (*105*), when combined with seat-belt use, they have been found to reduce the risk of death in frontal crashes by 68% (*106*). Estimates of the general effectiveness of air bags in reducing deaths in all types of crashes range from 8% to 14% (*106–108*). Where passenger air bags are fitted, however, clear instructions are needed to avoid fitting rear-facing child restraints on the same seat. Also required are devices to automatically detect child restraints and out-of-position occupants, and in such cases to switch off the passenger air bag.

Protection against roadside objects. Collisions between cars and trees or poles are characterized by the severity of the injuries produced. Current legislation only requires the use of crash tests with barriers representing car-to-car impacts. It may now be time to supplement these tests with front and side car-to-pole tests, as practised in some consumer testing programmes. Better coordination is required between the design of cars and that of safety barriers (*65, 109*).

Vehicle-to-vehicle compatibility

Achieving vehicle-to-vehicle compatibility in crashes depends upon the particular mix of motor vehicle. In the United States, for example, there is a greater need to reconcile sports utility vehicles and other light truck vehicles with passenger cars. The United States National Highway Traffic Safety Administration has made vehicle compatibility one of its leading priorities and has published its proposed initiatives in a recent report (*110*). In Europe, work focuses on trying to improve car-to-car compatibility for both front-to-front and front-to-side crashes and recommendations on this have been put forward (*83*). In low-income and middle-income countries, issues of vehicle-to-vehicle compatibility are related more to collisions between cars and trucks – both front-to-front impacts, as well as between the front of the car and the rear of the truck. The first priority for these countries must be to improve the geometry and structure of trucks so as to better accommodate impacts from smaller vehicles – not only cars, but motorcycles and bicycles as well (*82*).

The frontal structures of many new cars are capable of absorbing their own kinetic energy in crashes, so avoiding any significant intrusion of the passenger compartment. However, there is currently no legal control, by means of performance requirements, of the relative degrees of stiffness of the fronts of different models of car. Consequently, when cars of differing stiffness collide, the stiffer car crushes the weaker car (*83*).

Front, rear and side under-run guards on trucks

The provision of front and rear under-run protection on trucks is a well-established means of preventing "under-running" by cars (whereby cars go underneath trucks, because of a mismatch between the heights of car fronts and truck sides and fronts). Similarly, side protection prevents cyclists from being run over. It has been estimated that the provision of energy-absorbing front, rear and side under-run protection could reduce deaths by about 12% (*111*). It has also been suggested that the benefits would exceed the costs, even if the safety effect of these measures was as low as 5% (*56*).

Design of non-motorized vehicles

Research has shown that ergonomic changes in the design of bicycles could lead to an improvement in bicycle safety (*23, 112*). Bicycles display large differences in component strength and the reliability of their brakes and lighting. About three quarters of crashes involving passengers carried on bicycles in the Netherlands are associated with feet being trapped in the wheel spokes, and 60% of bicycles have no protective system to prevent this (*112*).

"Intelligent" vehicles

New technologies are creating new opportunities for road safety as more intelligent systems are being developed for road vehicles. Vehicles are now starting to be equipped with technology that could improve road safety in terms of exposure, crash avoidance, injury reduction and automatic post-crash notification of collision (*113*).

The development of intelligent systems is principally technology-driven. This means that – in the case of many of the features being promoted – the implications for road safety, as well as for the behavioural response of users and for public acceptance, have to be examined. It is generally acknowledged that some devices may distract drivers or affect their behaviour, often in a manner not anticipated by the designers of the system (*113, 114*). For these and other reasons, it has been strongly suggested that the development and application of intelligent transport systems should not be left entirely to market forces (*87, 113*).

Examples are presented below of some of the most promising "intelligent" vehicle safety applications that are already "on the road" in some form.

"Smart", audible seat-belt reminders

As discussed earlier, the fitting and use of seat-belts constitute the most important form of occupant restraint. Measures to increase seat-belt use, through legislation, information and enforcement and smart audible seat-belt reminders are central to improving in-car safety.

Seat-belt reminders are intelligent visual and audible devices that detect whether seat-belts are in use in various seating positions and give out increasingly urgent warning signals until the belts are used (*83*). They do not lock the ignition function. Modern types of seat-belt reminders are different from the older versions that produced a chiming sound and a light for four to eight seconds, which proved ineffective in increasing seat-belt use (*115*).

In Sweden, 35% of all new cars sold currently have seat-belt reminders (*116*). It is estimated in that country that reminders in all cars could lead to national levels of seat-belt use of around 97%, contributing to a reduction of some 20% in car occupant deaths (*117*).

User trials and research in Sweden and the United States have shown that seat-belt reminders with audible warnings are an effective means of increasing seat-belt use. Preliminary research on the only system currently available in the United States found a 7% increase in seat-belt use among drivers of cars with seat-belt reminders, compared with drivers of unequipped vehicles (*118*). Furthermore, a driver survey found that of the two thirds who activated the system, three quarters reported using their seat-belt, and nearly half of all respondents said their belt use had increased (*119*).

A recent United States National Academy of Science report urged the car industry to ensure that every new light-duty vehicle should have, as standard equipment, an enhanced seat-belt reminder system for front-seat occupants, with an audible warning and visual indicator that could not be easily disconnected (*120*).

An Australian analysis has estimated a cost–benefit ratio of 1:5, for a simple device for drivers only (*121*). A cost–benefit ratio of 1:6 was found when seat-belt reminders were introduced in new vehicles in European Union countries (*75*). Seat-belt reminders provide a cheap and efficient option for helping to enforce seat-belt use.

Speed adaptation

As stated elsewhere in this report, a variety of effective means exist to reduce vehicle speeds – including the setting of speed limits according to road function, better road design, and the enforcement of limits by the police, radar and speed cameras. Speed limitation devices in vehicles can assist this process, by controlling the maximum speed a vehicle can travel at; some devices are able to set variable limits (see below).

Insurance statistics show that high-speed cars – those with powerful engines, high acceleration and high top speeds – are more frequently involved in crashes than cars with lower speed capacities (*16*). The increase in maximum speeds in the past 30 to 40 years has made it increasingly easy to drive at inappropriately fast speeds, thus counteracting the effects of measures aimed at improving the safety of cars. In 1993, the ten best-selling models of cars had top speeds that were double the highest national posted speed limits in Norway (*16*).

Intelligent Speed Adaptation (ISA) is a system being developed that shows great promise in terms of its potential impact on the incidence of road casualties. With this system, the vehicle "knows" the permitted or recommended maximum speed for the road along which it is travelling.

The standard system uses an in-vehicle digital road map onto which speed limits have been coded, combined with a satellite positioning system. The level at which the system intervenes to control the speed of the vehicle can be one of the following:

- advisory – the driver is informed of the speed limit and when it is being exceeded;
- voluntary – the system is linked to the vehicle controls but the driver can choose whether and when to override it;
- mandatory – no override of the system is possible.

The potential reduction in the number of fatal crashes for these different types of systems has been estimated to be in the range 18–25% for advisory systems, 19–32% for voluntary systems, and 37–59% for mandatory systems (*122*). Speed limit information can in theory be extended to incorporate lower speeds at certain locations in the network and – in the future – can vary according to current network conditions, such as weather conditions, traffic density and the presence of traffic incidents on the road.

Experimental trials have been carried out or are under way in Australia, Denmark, the Netherlands, Sweden and the United Kingdom (*113*). By far the largest trial of a speed adaptation system – the three-year Intelligent Speed Adaptation project – was carried out in four municipalities in Sweden. Various types of ISA system were installed in around 5000 cars, buses and trucks. If the driver exceeded the speed limit, light and sound signals were activated. The trial was conducted primarily in built-up areas with speed limits of 50 km/h or 30 km/h, and the test drivers were both private car and commercial drivers. The Swedish National Road Administration reported a high level of driver acceptance in urban areas of the devices and suggested that they could reduce crash injuries by 20–30% in urban areas (*109, 116*).

Alcohol interlocks

Alcohol ignition interlocks are automatic control systems that are designed to prevent drivers who are persistently over the legal alcohol limit from starting their cars if their BAC levels are over the legal driving limit. In principle, these devices can be fitted in any car. As a deterrent, though, they can be fitted in the cars of repeat drink-driving offenders, who have to blow into the device before the car will start. If the driver's BAC is above a certain level, the car will not start. Such devices, when introduced in vehicles as part of a comprehensive monitoring programme, led to reductions of between 40% and 95% in the rate of repeated offending (*123*).

Around half of Canada's provinces and territories have embarked on alcohol interlock programmes and in the United States, most states have passed enabling legislation for such devices. Some states in Australia have small experimental programmes in progress, involving public transport and commercial road transport, and the European Union is conducting a feasibility study (*124*). In Sweden, alcohol interlocks are now installed in over 1500 vehicles and, since 2002, two major truck suppliers have been offering interlocks as standard equipment on the Swedish market (*116*).

If limited to use in dealing with drivers who are persistently over the legal alcohol limit, alcohol interlock devices might have only a numerically small impact. However, their wider use in public and commercial transport in the future could extend the potential impact of this tool in dealing with the problem of drink-driving.

On-board electronic stability programmes

Weather conditions can affect the control of vehicles and increase the risk of skidding and crashes due to loss of control on wet or icy roads. In such conditions an electronic stability programme – an on-board car safety system – can help the car to remain stable during critical manoeuvring. Such devices are now being introduced onto the market, but they are very expensive. A recent Swedish evaluation of the effects of this new technology – the first of its kind – produced promising results, especially for bad weather conditions, with reductions in injury crashes of 32% and 38% on ice and snow, respectively (*125*).

Setting and securing compliance with key road safety rules

Good enforcement is an integral part of road safety. Self-enforcing road safety engineering measures, as well as new and existing vehicle technologies that influence the behaviour of road users have already been discussed. This section examines the role of traffic law enforcement by the police and the use of camera technology.

A major review on traffic law enforcement identified several important findings (*126*):

- It is critical that the deterrent be meaningful for the traffic law enforcement to be successful.
- Enforcement levels need to be high and maintained over a period of time, so as to ensure that the perceived risk of being caught remains high.

- Once offenders are caught, their penalties should be dealt with swiftly and efficiently.
- Using selective enforcement strategies to target particular risk behaviours and choosing specific locations both improve the effectiveness of enforcement.
- Of all the methods of enforcement, automated means – such as cameras – are the most cost-effective.
- Publicity supporting enforcement measures increases their effectiveness; used on its own, publicity has a negligible effect on road user behaviour.

A study in Canada found that the enforcement of traffic rules reduced the frequency of fatal motor vehicle crashes in highly-motorized countries. At the same time, inadequate or inconsistent enforcement could contribute to thousands of deaths worldwide every year (*127*). It has been estimated that if all current cost-effective traffic law enforcement strategies were rigorously applied by European Union countries, then as many as 50% of deaths and serious injuries in these countries might be prevented (*128*).

Setting and enforcing speed limits

Setting road speed limits is closely associated with road function and road design, as already mentioned. Physical measures related to the road and the vehicle, as well as law enforcement by the police, all contribute to ensuring compliance with maximum posted speed limits and to the choice of an appropriate speed for the existing conditions.

Much research and international experience point to the effectiveness of setting and enforcing speed limits in reducing the frequency and severity of road crashes (*16, 129*). Some examples of the impacts of changes in speed limits are given in Table 4.4. In addition, the use of variable speed limits – where different speed limits are imposed at different times on the same stretch of road – can be effective in managing speed (*128, 130*).

Speed enforcement on rural roads

A meta-analysis of speed enforcement on rural roads, either by means of radar or instruments which measure mean vehicle speed between two fixed points, or by stationary speed enforcement – where uniformed police officers and police cars attend vehicle stopping points – found that the two strategies combined reduced fatal crashes by 14% and injury crashes by 6%. Stationary speed enforcement alone reduced fatal and injury crashes by 6% (*16*).

Leggett described a long-term, low-intensity speed enforcement strategy in Tasmania, Australia, that involved the visible use of single, stationary police vehicles on three high-risk stretches of rural road (*131*). This enforcement strategy resulted in an observed reduction in speeding behaviour and a significant decrease in the overall average speed of 3.6 km/h. A fall of 58% in serious casualty crashes – fatal crashes and those involving hospital admission – was also reported. The two-year enforcement programme produced an estimated cost–benefit ratio of 1:4 (*131*).

TABLE 4.4

Examples of effects of speed limit changes

Date	Country	Type of road	Speed limit change	Effect of change on speed	Effect of change on number of fatalities
1985	Switzerland	Motorways	130 km/h to 120 km/h	5 km/h decrease in mean speeds	12% reduction
1985	Switzerland	Rural roads	100 km/h to 80 km/h	10 km/h decrease in mean speeds	6% reduction
1985	Denmark	Roads in built-up areas	60 km/h to 50 km/h	3–4 km/h decrease in mean speeds	24% reduction
1987	USA	Interstate highways	55 miles/h (88.5 km/h) to 65 miles/h (104.6 km/h)	2–4 miles/h (3.2–6.4 km/h) increase in mean speeds	19–34% increase
1989	Sweden	Motorways	110 km/h to 90 km/h	14.4 km/h decrease in median speeds	21% reduction

Source: reproduced from reference *130,* with the permission of the publisher.

Speed cameras

Automatic speed enforcement, such as by means of speed cameras, is now employed in many countries. Experience from a range of high-income countries indicates that speed cameras that record photographic evidence of a speeding offence, that is admissible in a law court, are a highly effective means of speed enforcement (see Table 4.5). The well-publicized use of such equipment in places where speed limits are not generally obeyed and where the consequent risk of a crash is high has led to substantial reductions in crashes (*113, 132, 134*). The cost–benefit ratios of speed cameras have been reported to range between 1:3 and 1:27 (*135, 136*). In several countries, including Finland, Norway and the United Kingdom, there has been a high social acceptance of speed cameras (*113*).

Speed limiters in heavy goods and public transport vehicles

Speed can also be controlled by "vehicle speed limiters" or "speed governors", which are devices that can be added to vehicles to limit the maximum speed of the vehicle. This device is already being used in many countries in heavy goods vehicles and coaches. It has been estimated that speed governors on heavy goods vehicles could contribute to a reduction of 2% in the total number of injury crashes (*137*).

In rural areas, speed limitation for buses, minibuses and trucks could be valuable (*46*). Given the high representation of such vehicles in injury crashes in low-income countries, universal availability of speed limitation on trucks and buses would be an important means of improving road safety.

Setting and enforcing alcohol impairment laws

Despite the progress made in many countries in curbing drink-driving, alcohol is still a significant and widespread factor in road crashes. The scientific literature and national road safety programmes agree that a package of effective measures is necessary to reduce alcohol-related crashes and injuries.

Blood alcohol concentration limits

The basic element of any package to reduce alcohol impairment among road users is establishing a legal BAC limit. In many countries, a breath alcohol limit is used, for purposes of legal prosecution. Mandatory BAC limits provide an objective and simple means by which alcohol impairment can be detected (*138*). In addition, the BAC level gives clear guidance to drivers about safe driving practice. Upper limits of 0.05 g/dl for the general driving population and 0.02 g/dl for young drivers and motorcycle riders are generally considered to be the best practice at this time.

TABLE 4.5

Estimated safety benefits of speed cameras

Country or area	Benefits of crash reduction at a system level	Benefits of crash reduction at individual crash sites
Australia	22% reduction in all crashes in New South Wales 30% reduction in all crashes on urban arterial roads in Victoria 34% reduction in fatal crashes in Queensland	
New Zealand		11% reduction in crashes and 20% reduction in casualties during trials of hidden speed cameras
Republic of Korea		28% reduction in crashes and 60% reduction in deaths at high-risk sites
United Kingdom		35% reduction in road traffic deaths and serious injuries and 56% reduction in pedestrians killed or seriously injured at camera site
Europe (various)	50% reduction in all crashes	
Various countries (meta-analysis)	17% reduction in crashes resulting in injuries 28% reduction in all crashes in urban areas 4% reduction in all crashes in rural areas	

Sources: references *16, 113, 132, 133.*

Blood alcohol concentration limits for the general driving population

The risk of crash involvement starts to increase significantly at BAC levels of 0.04 g/dl (*139*). A variety of BAC limits are in place across the world – ranging from 0.02 g/dl to 0.10 g/dl (see Table 4.6). The most common limit in high-income countries is 0.05 g/dl; a legal limit of 0.10 g/dl corresponds to a three-fold increase, and a limit of 0.08 g/dl a two-fold increase, in the risk of crash involvement over that allowed by a 0.05 g/dl limit.

TABLE 4.6

Blood alcohol concentration (BAC) limits for drivers by country or area

Country or area	BAC (g/dl)	Country or area	BAC (g/dl)
Australia	0.05	Lesotho	0.08
Austria	0.05	Luxembourg	0.05
Belgium	0.05	Netherlands	0.05
Benin	0.08	New Zealand	0.08
Botswana	0.08	Norway	0.05
Brazil	0.08	Portugal	0.05
Canada	0.08	Russian Federation	0.02
Côte d'Ivoire	0.08	South Africa	0.05
Czech Republic	0.05	Spain	0.05
Denmark	0.05	Swaziland	0.08
Estonia	0.02	Sweden	0.02
Finland	0.05	Switzerland	0.08
France	0.05	Uganda	0.15
Germany	0.05	United Kingdom	0.08
Greece	0.05	United Republic of Tanzania	0.08
Hungary	0.05	United States of America[a]	0.10 or 0.08
Ireland	0.08	Zambia	0.08
Italy	0.05	Zimbabwe	0.08
Japan	0.00		

[a] Depends on state legislation.
Sources: references *140–142*.

Reviews of the effectiveness of introducing BAC limits for the first time have found that they lead to reductions in alcohol-related crashes, though the magnitude of these effects varies considerably. When limits are subsequently decreased, research shows that this is generally accompanied by further reductions in alcohol-related crashes, injuries and deaths (*138*). Reducing BAC limits from 0.10 g/dl to 0.08 g/dl (as was done in some states in the United States) or from 0.08 g/dl to 0.05 g/dl (in Australia) or from 0.05 g/dl to 0.02 g/dl (in Sweden) resulted in a fall in the number of deaths and serious injuries (*143–145*). In the United States, a systematic review of BAC laws in 16 states found that the reduction from 0.10 g/dl to 0.08 g/dl resulted in a median decrease of 7% in fatal alcohol-related motor vehicle crashes (*145*).

Lower blood alcohol concentration limits for young or inexperienced drivers

As already discussed in the previous chapter, the crash risk for inexperienced young adults starts to increase substantially at lower BAC levels than older, more experienced drivers.

A review of published studies found that laws establishing a lower BAC limit – of between zero and 0.02 g/dl – for young or inexperienced drivers can lead to reductions in crashes of between 4% and 24% (*145*). In the United States, where a lower BAC limit applies to all drivers under the age of 21 years, it has been estimated that the cost–benefit ratio of the measure is 1:11 (*146*). In other countries, there are lower legal BAC limits for newly-licensed drivers, or for newly-licensed drivers under a certain age, which form part of a graduated driver licensing scheme.

Minimum drinking-age laws

Minimum drinking-age laws specify an age below which the purchase or public consumption of alcoholic beverages is illegal. In the United States, the minimum drinking age in all 50 states is currently 21 years. A systematic review of 14 studies from various countries looking at the effects of raising minimum drinking ages found that crash-related outcomes decreased on average by 16% for the targeted age groups. In nine studies that examined the effects of lowering the drinking-age, crash-related outcomes increased by an average of 10% within the age groups concerned (*145*).

Deterring excess alcohol offenders

For most countries, the level of enforcement of drink-driving laws has a direct effect on the incidence of drinking and driving (*147*). Increasing drivers' perception of the risk of being detected is the most effective means of deterring drinking and driving (*148*). "Evidential" breath-testing devices (devices that are considered accurate enough for the results to be used as evidence in law courts) are a means of substantially increasing breath-testing activity. Though used in most high-income countries, they are not currently widespread elsewhere. This greatly limits the ability of many countries to respond effectively to the problem of drink-driving.

The deterrent effect of breath-testing devices is to a large extent dependent on the legislation governing their use (*126*). Police powers vary between countries, and include the following:

— stopping obviously impaired drivers;
— stopping drivers at roadblocks or sobriety checkpoints and testing only those suspected of alcohol impairment;
— stopping drivers at random and testing all who are stopped.

The following components have been identified as being central to successful police enforcement operations to deter drinking drivers (*128*):

- A high proportion of people tested (at least one in ten drivers every year but, if possible, one in three drivers, as is the case in Finland). This can only be achieved through wide-scale application of random breath testing and evidential breath testing.
- Enforcement that is unpredictable in terms of time and place, deployed in such a manner so as to ensure wide coverage of the whole road network and to make it difficult for drivers to avoid the checkpoints.
- Highly visible police operations. For drinking drivers who are caught, remedial treatment can be offered as an alternative to traditional penalties, to reduce the likelihood of repeated offending.

Random breath testing and sobriety checkpoints

Random breath testing is carried out in several countries, including Australia, Colombia, France, the Nordic countries, the Netherlands, New Zealand and South Africa. The use of sustained and intensive random breath testing is a highly effective means of reducing injuries resulting from alcohol impairment. In Australia, for instance, since 1993 it has led to estimated reductions in alcohol-related deaths in New South Wales of 36% (with one in three drivers tested), in Tasmania of 42% (three in four tested) and in Victoria of 40% (one in two tested) (*126*).

An international review of the effectiveness of random breath testing and sobriety checkpoints found that both reduced alcohol-related crashes by about 20% (*149*). The reductions appeared to be similar, irrespective of whether the checkpoints were used for short-term intensive campaigns or continuously over a period of several years.

A Swiss study has shown that random breath testing is one of the most cost-effective safety measures that can be employed, with a cost–benefit ratio estimated at 1:19 (*150*). In New South Wales, Australia, the estimated cost–benefit ratio of random breath testing ranged from 1:1 to 1:56 (*126, 151, 152*). Similarly, economic analyses on the sobriety checkpoint programmes in the United States estimated benefits totalling between 6 and 23 times their original cost (*153, 154*).

Mass media campaigns

It is generally accepted that enforcement of alcohol impairment laws is more effective when accompanied by publicity aimed at:

— making people more alert to the risk of detection, arrest and its consequences;
— making drinking and driving less publicly acceptable;
— raising the acceptability of enforcement activities.

Public support for random breath testing, for instance, has remained high in New South Wales, Australia as a result of extensive public information concerning the measure.

A recent systematic review demonstrated that mass media campaigns that are carefully planned and well executed, that reach a sufficiently large audience, and that are implemented together with other prevention activities – such as highly-visible enforcement – are effective in reducing alcohol-impaired driving and alcohol-related crashes (*155*). In New Zealand, a recent evaluation of the five-year Supplementary Road Safety Package, which combines shock advertising with enforcement, found that this combination strategy saved between 285 and 516 lives over the five-year period (*156*).

Penalties for excess alcohol offenders

Prison sentences have been given for drink-driving offences in several countries, including Australia, Canada, Sweden and the United States. According to research, though, in the absence of effective enforcement such a penalty, in general, has been unsuccessful in deterring drinking drivers or reducing the rate of repeat offending (*148, 157*). If drivers perceive that the likelihood of their being detected and punished is low, then the effect of the penalty, even if severe, is likely to be small. All the same, research suggests that disqualification from driving after failing a breath test or refusing to take a breath test may deter drinking drivers – probably because of the swiftness and certainty of the punishment (*157*).

Interventions for high-risk offenders

High-risk offenders are usually defined as those with BAC levels in excess of 0.15 g/dl. In many industrialized countries, driver rehabilitation courses are available to offenders, though the components of such courses vary widely. Studies that have followed participants subsequent to drink-driving rehabilitation courses have shown, where participants are motivated to address their problems, that the courses reduce the rate of reoffending (*158, 159*).

Medicinal and recreational drugs

Legal requirements for police powers to carry out drug testing vary. Powers to carry out a blood or urine test exist in many countries to determine whether a driver is unfit to drive as a result of consuming drugs. The relationship between the use of drugs and involvement in road crashes is still largely unclear. Considerable research, though, is currently being undertaken to gain greater understanding of this subject. Enforcement strategies that deter people from driving while under the influence of drugs still have to be developed. Research is also being carried out in this area, to find efficient and cost-effective screening devices to help enforce laws on drug use and driving.

Drivers' hours of work in commercial and public transport

The previous chapter outlined the risks associated with cumulative fatigue as a result of lack of sleep, night driving and working shifts. Research indicates that fatigue is most prevalent among long-distance truck drivers (*160*) and that it is a factor in 20–30% of crashes in Europe and the United States involving commercial road vehicles (*161, 162*). A recent review of research on fatigue among commercial transport drivers in Australia found that between 10% and 50% of truck drivers drove while fatigued on a regular basis. The self-reported use of pills taken to stay awake in the long-distance road transport industry varies between 5% and 46% (*163*).

The normal pattern of work of commercial drivers is influenced by strong economic and social forces. Arguments about safety are usually ignored in many places, for commercial reasons (*161, 164–166*). However, an estimated 60% of the overall costs of traffic crashes involving commercial trucks in the United States are borne by society, rather than by the truck operators (*167*).

Working time – which often determines the time since the last significant period of sleep – is more critical to fatigue than actual driving time. Restrictions on driving hours that do not take into account when the driving occurs, forcing drivers to work according to shifting schedules, can result in greater sleep deprivation and make it difficult for the drivers' circadian rhythms to adapt (*161*).

Buses, coaches and commercial road transport are the only areas that are covered by specific legislation. It is increasingly recognized, though, that regulations on working and driving times need to be broadened. Drivers and operators, for instance, need training and information on fatigue and how to manage it. In Europe, in particular, laws on driving and working hours and their enforcement, over the last 30 years, have not yet reached the levels demanded by safety research (*161*). Safety experts believe that the policies on driving and working hour limits should take greater account of the scientific evidence on fatigue and crash risk and, in particular, of the following:

- *Daily and weekly rest*. The risk of being involved in a crash doubles after 11 hours of work (*168*). Sufficient time and proper facilities for meal breaks and daily rest and recuperation need to be provided. Where breaks cannot be taken at physiologically suitable times of the day, proper time must be given for full recuperation on a weekly, or shorter, basis.
- *Night work*. The risk of fatigue-related crashes at night is 10 times greater than during the day (*161*). The number of permissible working hours during the period of low circadian activity should be substantially less than the number permitted during the day.
- *Working and driving time*. There should be a coordinated approach to regulating driving and working time to ensure that permissible driving times do not inevitably lead to unacceptably high working times that double crash risk.

Some new vehicle technologies – such as on-board driver monitoring systems – promise to help in the detection of fatigue and excessive working hours. Road design standards urgently need to take better account of current knowledge of the causes and characteristics of crashes due to fatigue and inattention, and more research is needed to set good standards of road design to help prevent such crashes (*163*). While such technological advances can certainly help, none of them is a substitute for a proper regime of regulated working hours and its rigorous enforcement.

Cameras at traffic lights

Crashes at junctions are a leading source of road traffic injury. In addition to improved junction layout and design and the replacement, where appropriate, of signal-controlled junctions by roundabouts, research has shown that cameras can also be cost-effective in reducing crashes at junctions with traffic lights. Cameras at traffic lights take photographs of vehicles going through the lights when the signal is red. In Australia, the introduction of such cameras in the late 1980s led to a 7% reduction in all crashes and a 32% reduction in front-to-side impacts at sites with cameras (*169*). In the United States, it was found that following the introduction of cameras at sites in Oxnard, California, the number of injury crashes fell by 29% and the number of front-to-side impacts involving injury fell by 68%, with no increase in rear impacts (*170*). A meta-analysis of studies of the effectiveness of cameras at traffic lights has shown that they are associated with a 12% reduction in the number of injury crashes (*16*). A cost–benefit analysis of cameras at traffic lights in the United Kingdom calculated that the return was nearly twice the investment after one year and 12 times the investment after five years (*171*).

Setting and enforcing seat-belt and child restraint use

Seat-belts

The level of seat-belt use is influenced by:

— whether there is legislation mandating their use;

— the degree to which enforcement of the law, complemented by publicity campaigns, is carried out;

— incentives offered to encourage use.

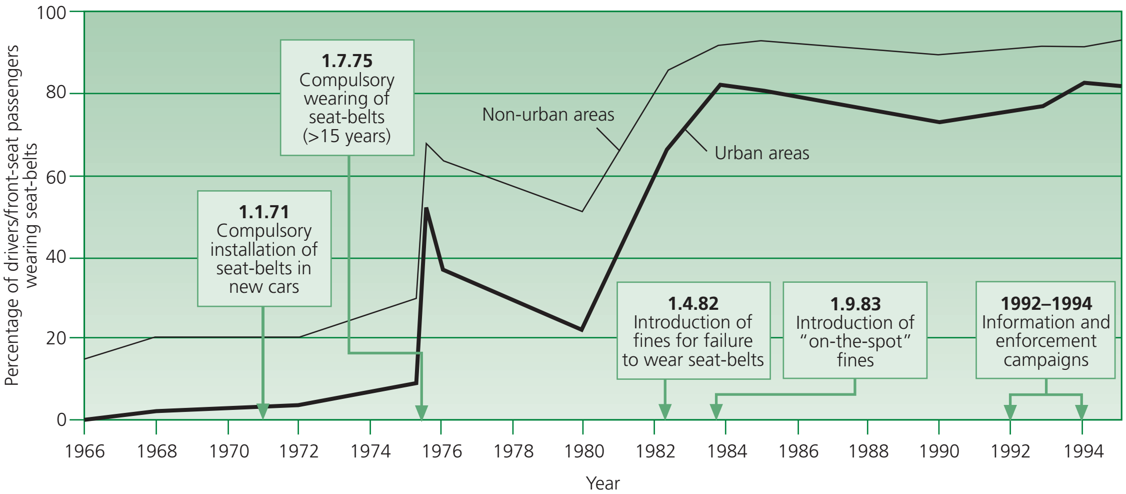
The time series shown in Figure is 4.1 is based on 30 years of experience in Finland with using seat-belts. It shows how legislation for compulsory use, without accompanying penalties, publicity or enforcement, has only a temporary effect on usage rates.

Mandatory seat-belt use laws

Mandatory seat-belt use has been one of road injury prevention's greatest success stories and has saved many lives. Occupant restraints first began to be fitted in cars in the late 1960s, and the first law on their mandatory use was passed in Victoria, Australia, in 1971. By the end of that year, the annual number of car occupant deaths in Victoria had fallen by 18%, and by 1975 by 26% (*173*). Following the experience of Victoria, many countries also introduced seat-belt laws, which have led to many hundreds of thousands of lives saved worldwide.

FIGURE 4.1

Use of seat-belts by car drivers/front-seat passengers in urban and non-urban areas of Finland, 1966–1995



Source: reference *172*.

Seat-belts had been available for 20 years in Europe before their use was enforced by law, often with dramatic results. In the United Kingdom, for instance, front seat-belt usage rose from 37% before the introduction of the law to 95% a short period afterwards, with an accompanying fall of 35% in hospital admissions for road traffic injuries (*174, 175*). The wide variation in seat-belt use in European Union countries means that substantial further savings – estimated at around 7000 deaths annually – could be achieved if the usage rate was raised to the best that exists globally. In 1999, the best rates for seat-belt use recorded in high-income countries were in the 90–99% range for front-seat occupants, and in the 80–89% range for those in rear seats (*128*). Seat-belt use legislation in low-income countries is still not universal, and will become increasingly important as levels of car traffic rise.

The cost–benefit ratio of mandatory seat-belt use has been estimated at between 1:3 and 1:8 (*16*).

Enforcement and publicity

Research has shown that *primary enforcement* – where a driver is stopped solely for not wearing a seat-belt – is more effective than *secondary enforcement* – where a driver can only be stopped if another offence has been committed (*176, 177*). Primary enforcement can increase seat-belt use, even where the level of use is already high (*178*).

Many studies, at both national and local levels, have shown that enforcement increases seat-belt use if it meets certain conditions. The enforcement needs to be selective, highly visible and well publicized, conducted over a sufficiently long period and repeated several times during a year (*179–183*). Selective Traffic Enforcement Programmes and similar programmes have been introduced in France, in parts of the Netherlands and in several states of the United States. Generally, wearing rates have been found to be around 10–15% higher than the baseline level, a year after the activities were carried out (*184*). Studies have estimated that the cost–benefit ratio of such seat-belt enforcement programmes is of the order of 1:3 or more (*172*).

The Selective Traffic Enforcement Programmes carried out in Canadian provinces have achieved improvements in seat-belt use, resulting in high rates of use. While the programmes differ across provinces in their details, their basic elements are broadly similar and include:

- an information briefing, educating police forces about the issue and its importance;
- following this campaign, a period of one to four weeks of intensive enforcement by

the police, including fines, repeated several times a year;
— extensive public information and advertising;
— support for the enforcement campaigns in the media, and regular feedback in the media to public and police, on the progress recorded.

In the province of Saskatchewan, the programme has been repeated every year since 1988. In 1987, prior to the start of the programme seat-belt use of drivers was 72%, and that of front-seat passengers 67%. Figure 4.2 shows the incremental increases in seat-belt use – up to rates in excess of 90% – of drivers and front-seat passengers, from the introduction of the programme until 1994 (*185, 186*).

The reasons why this type of programme has had such success include (*186*):

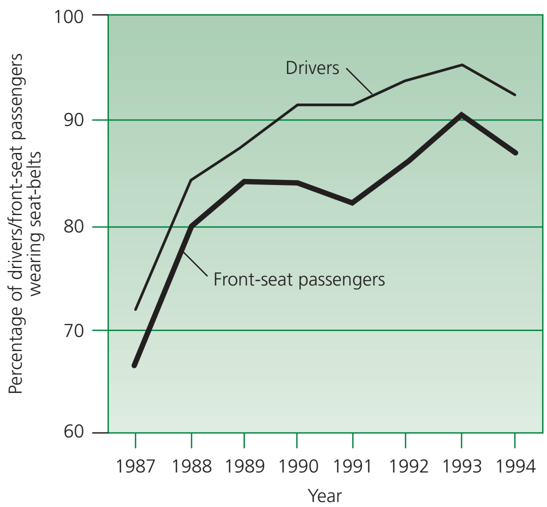
- The programme is seen as a safety, rather than as an enforcement measure, as a result of public information before the programme started.
- The perceived risk of being caught is increased, because of the wide media coverage and police visibility.
- The provision of incentives (see below) strengthens the safety message and results in even higher police visibility.
- Feedback on the programme's progress motivates both the public and police.
- The programme is greater than the sum of its separate elements, that is to say, its individual elements reinforce each other.

In the Republic of Korea, in the second half of 2000, the government set a target to increase seat-belt use from 23% to 80% by 2006. By August 2001, efforts to increase seat-belt use that included publicity, enforcement and a 100% increase in fines for offenders, led to a spectacular increase in usage from 23% to 98%, a rate that was sustained in 2002 (*133*).

Six months after the introduction of legislation on seat-belt use in Thailand, a study in four cities found that the proportion of drivers wearing seat-belts had actually decreased. The reason for this is unclear, but it may have been related to problems with the consistent enforcement of the law (*187*).

FIGURE 4.2

Use of seat-belts by car drivers/front-seat passengers in Saskatchewan, Canada, 1987–1994



Source: reference *185*.

Incentive programmes

Incentives programmes have been devised to enhance police enforcement of seat-belt use in a number of countries. In these programmes, seat-belt use is monitored and seat-belt wearers are eligible for a reward. The rewards may range from a meal voucher or lottery ticket to sizeable prizes such as video recorders or free holidays (*188*). In general, such programmes appear very effective and have a high level of acceptance. A meta-analysis of 34 studies examined the effects of incentives on seat-belt use, and found the size of the effect to be related to a number of variables, such as the target population, the initial baseline rate of seat-belt use and the prospect of immediate rewards (*184*).

Child restraints

The high level of effectiveness of child restraints in reducing fatal and serious injuries was discussed in the previous chapter. Good protection requires that the type of restraint used is appropriate for the age and weight of the child. Several restraint types exist and are covered by international standards. These include (*189*):

- *Rear-facing infant seats*: for infants up to 10 kg, from birth to 6–9 months, or for infants up to 13 kg, from birth to 12–15 months.

- *Forward-facing child seats*: for children weighing 9–18 kg, from approximately 9 months to 4 years.
- *Booster seats*: for children weighing 15–25 kg, aged from about 4 to 6 years.
- *Booster cushions*: for children weighing 22–36 kg, aged from about 6 to 11 years.

Effective interventions for increasing child restraint use include (*172, 190*):

— laws mandating child restraints;
— public information and enhanced enforcement campaigns;
— incentive programmes and education programmes to support enforcement;
— child restraint loan schemes.

In North America, children under 12 years are encouraged to sit in the rear of the vehicle, whereas in Europe, rear-facing child seats are increasingly being used on the front passenger seat. As mentioned in the previous chapter, while research has shown that rear-facing seats offer more protection than forward-facing seats, there are risks attached to placing rear-facing seats on the front seat directly in front of the passenger air bag. There should be clear instructions to avoid fitting rear-facing child restraints in this way. Devices exist that can automatically detect child restraints and occupants out of their normal position on the front seat, and switch off the passenger air bag.

As regards child restraint usage in low-income countries, cost and availability are important factors.

Mandatory child restraint laws

A review of studies on the effects of mandatory child restraint laws in the United States concluded that such laws have led to an average reduction of 35% in fatal injuries, a 17% decrease in all injuries and a 13% increase in child restraint use (*190, 191*).

While most cars in high-income countries are fitted with adult restraint systems, child restraint use requires informed decisions on the part of parents or guardians regarding design, availability and correct fitting. A further issue is the fact that age-related child seats can only be used for a limited period and the cost of replacing them could deter parents from doing so.

As mentioned earlier, the incorrect fitting and use of child equipment is a significant problem that decreases the potential safety benefits of these systems. Standardized anchorage points in cars would help to resolve many of these problems. Proposals for an international requirement have been discussed for many years, but not agreed as yet.

In the absence of child seats, it is important that adults are made to understand that they should avoid carrying children on their laps. The forces in a crash are such that, whatever action adults may take, they are unlikely to save an unbelted child from injury (*192*).

Child restraint loan programmes

Child restraint loan programmes are widely available in high-income countries. For a small fee or without charge, parents can have the loan of an infant seat from the maternity ward where the child is born. A further benefit of such schemes is their strong educational value and the opportunity they afford for precise advice to be given to the parents. The schemes have strongly affected usage rates of infant seats and also the use of appropriate child restraints throughout childhood (*191, 193*).

Setting and enforcing mandatory crash helmet use

Bicycle helmets

As already mentioned, the use of bicycle helmets has been found to reduce the risk of head and brain injuries by between 63% and 88% (*194–196*). As with other safety equipment, measures to increase the use of bicycle helmets involve a variety of strategies. A range of bicycle helmet standards is used worldwide. While there continues to be debate about whether mandatory use is appropriate – reflecting concerns that mandatory use could deter people from the otherwise healthy pursuit of cycling – the effectiveness of bicycle helmets for road safety is not at all in doubt (*195*) (see Box 4.5). In general, bicycle helmet use worldwide is low.

A meta-analysis of studies has shown that the mandatory wearing of cycle helmets has reduced the number of head injuries among cyclists by around 25% (*16*). In 1990, following 10 years of campaigns promoting the use of cycle helmets, the state of Victoria in Australia introduced the world's first law requiring cyclists to wear helmets. The rate of helmet wearing increased from 31% immediately before to 75% in the year following the new legislation and was associated with a 51% reduction in the numbers of crash victims who were admitted to hospital with head injuries or who died. Substantial increases in use were observed among all age groups, although rates of use were lowest among teenagers (*205*). Mandatory bicycle helmet laws introduced in New Zealand in 1994 also resulted in large increases in helmet use, and reductions in the number of head injuries of between 24% and 32% in non-motorized vehicle crashes and of 19% in motor vehicle crashes (*203*). Currently the rate of helmet wearing in New Zealand is around 90%, in all age groups (*206*).

Together with legislation on their use, helmet promotion programmes organized by community-wide groups, using a variety of educational and publicity strategies, have been shown to be effective in increasing helmet wearing in the United States (*207*). A law in Florida, United States, requires all riders under 16 years to wear a helmet; its introduction, which was accompanied by supporting strategies such as programmes in school on bicycle safety and the provision of free helmets for poorer people, led to a decline in the rate of bicycle-related injuries, from 73.3 to 41.8 per 100 000 population (*208*). In Canada, rates of helmet use rose rapidly following the introduction of mandatory laws for cyclists, and these rates were sustained over the next two years with regular education and enforcement by the police (*198*).

Cost–benefit ratios for cycle helmets have been estimated at around 1:6.2 for children, 1:3.3 for young adults and 1:2.7 for adults (*16*).

Motorcycle helmets

There are various strategies that effectively address the problem of head injuries in motorcyclists. They

BOX 4.5

Bicycle helmets

The incidence of bicycle-related injuries varies between countries. This is partly due to factors such as the road design, the traffic mix, climate and cultural attitudes (*197*). Over three quarters of fatal bicycle injuries are due to head injury (*198*). Among children, bicycle injuries are the leading cause of head injury (*199*).

There is now good evidence that bicycle helmets are effective in reducing head injuries. Early population-based research found that bicycle helmets reduced the risk of this type of injury by about 85% (*200*). More recent studies agree with this finding, with the estimated protective effects ranging from 47% to 88% (*195, 201*).

To promote the wearing of bicycle helmets, many governments have introduced legislation making bicycle helmets mandatory. During the 1990s, Australia, Canada, New Zealand and the United States brought in such laws. Since then, the Czech Republic, Finland, Iceland and Spain have followed suit. In the majority of cases, the laws have been directed at children and young people up to 18 years of age; only in Australia and New Zealand does the legislation cover bicyclists of all ages (*197*).

Evaluations of mandatory bicycle helmet laws have been encouraging. Findings from Canada, for instance, in those provinces where legislation has been introduced, show a 45% reduction in the rates of bicycle-related head injury (*202*). In New Zealand, it has been estimated that there was a 19% reduction in head injuries among cyclists over the first three years, following the introduction of bicycle helmet laws (*203*).

Those opposed to bicycle helmet legislation argue that wearing bicycle helmets encourages cyclists to take greater risks and therefore makes them more likely to incur injuries. To date, this argument has not found empirical evidence to support it. Other opponents have suggested that bicycle helmet legislation reduces the number of cyclists and it is for this reason that there are fewer head injuries. The most recent evidence, though, suggests the contrary: the number of child cyclists in Canada actually increased in the three years following the introduction of bicycle helmet laws (*204*).

There is unequivocal evidence that bicycle helmets reduce both the incidence and severity of head, brain and upper facial injuries. Making the wearing of bicycle helmets compulsory, together with improvements to the road environment that improve safety for cyclists, is therefore an effective strategy for reducing bicycle-related injuries.

include the introduction of performance standards for motorcycle safety helmets, legislation making helmet wearing compulsory – with penalties for non-use – and targeted information and enforcement campaigns.

In many parts of the world, helmet standards set out performance requirements for crash helmets. These standards are most effective when based on research findings on crash injury. A recent European initiative has recently reviewed, and subsequently revised, existing helmet standards in the light of current knowledge and crash research (*209*).

In low-income countries, it would be highly desirable for effective, comfortable and low-cost helmets to be developed and local manufacturing capacity increased. The Asia Injury Prevention Foundation, for instance, has developed a lightweight tropical helmet for use in Viet Nam and has drawn up standards for helmet performance. In Malaysia, the first standard for motorcycle helmets for adults was drafted in 1969 and updated in 1996. The country is now developing helmets specially designed for children (*210*).

Mandatory laws on helmet wearing

Increasing helmet wearing through the legislation requiring their use is important, especially in low-income countries where motorized two-wheeler use is high and current levels of helmet wearing low. It has been suggested that when a motorcycle is purchased, the acquisition of an approved helmet should be mandated, or at least encouraged, especially in low-income countries (*17*).

In Malaysia, where legislation on the use of helmets was introduced in 1973, it was estimated that the law led to a reduction of about 30% in motorcycle deaths (*211*). In Thailand, in the year following the enforcement of the law on wearing helmets, their use increased five-fold, while motorcycle head injuries decreased by 41.4% and deaths by 20.8% (*212*).

An evaluation of helmet use and traumatic brain injury, before and after the introduction of legislation, in the region of Romagna, Italy, found that helmet use increased from an average of less than 20% in 1999 to over 96% in 2001, and was an effective measure for preventing traumatic brain injury at all ages (*213*).

A meta-analysis of studies – mainly from the United States, where many laws on helmets were introduced in the period 1967–1970, around a half of which were repealed between 1976 and 1978 – found that the introduction of laws on compulsory helmet wearing reduced the number of injuries to moped riders and motorcyclists by 20–30% (*16*). Similarly, the analysis of the effects of repealing helmet wearing laws showed that withdrawing them led to an increase of around 30% in the numbers of fatal injuries, and an increase of 5–10% in injuries to moped riders and motorcyclists (*16*). A recent study on the repeal of laws in the United States found that observed helmet use in the states of Kentucky and Louisiana dropped from nearly full compliance, when the laws were still operative, to around 50%. After the repeal of the laws, motorcycle deaths increased by 50% in Kentucky and by 100% in Louisiana (*214*).

Economic evaluations of mandatory helmet wearing laws, based largely on experience in the United States, found high cost–benefit ratios, ranging from 1:1.3 to 1:16 (*215*).

The role of education, information and publicity

Public health sector campaigns in the field of road injury prevention have encompassed a wide range of measures, but education has always featured as the mainstay of prevention (*216*). In the light of ongoing research and experience of the systems approach to road injury prevention, many professionals in the field have re-examined the role that education plays in prevention (*26, 216, 217*). It is clear that informing and educating road users can improve knowledge about the rules of the road and about such matters as purchasing safer vehicles and equipment. Basic skills on how to control vehicles can be taught. Education can help to bring about a climate of concern and develop sympathetic attitudes towards effective interventions. Consultation with road users and residents is essential in designing urban safety management schemes.

As the previous section showed, when used in support of legislation and law enforcement, publicity and information can create shared social norms for safety. However, when used in isolation, education, information and publicity do not generally deliver tangible and sustained reductions in deaths and serious injuries (*26, 190, 217*). Historically, considerable emphasis has been placed on efforts to reduce road user error through traffic safety education – for example, in pedestrian and cycle education for school children, and in advanced and remedial driver training schemes. Although such efforts can be effective in changing behaviour (*218*), there is no evidence that they have been effective in reducing rates of road traffic crashes (*218, 219*) (see Box 4.6).

Delivering post-crash care

Chain of help for patients injured in road crashes

The aim of post-impact care is to avoid preventable death and disability, to limit the severity of the injury and the suffering caused by it, and to ensure the crash survivor's best possible recovery and reintegration into society. The way in which those

BOX 4.6

Educational approaches to pedestrian safety

Educating pedestrians on how to cope with the traffic environment is considered an essential component of strategies to reduce pedestrian injuries and has been recommended in all types of countries.

In order to reach the two groups of pedestrians that are particularly vulnerable – children and older people – educational programmes use a variety of methods, frequently in combination. These approaches include talks, printed materials, films, multi-media kits, table-top models, mock-ups of intersections, songs and other forms of music. Education is provided either directly to the target population or indirectly – through parents or teachers, for instance – and in various settings, such as the home, the classroom or a real traffic situation.

Most studies on the effectiveness of educational programmes report on surrogate outcomes, such as observed or reported behaviour, attitudes and knowledge. From a public health perspective, though, the main outcomes of interest are crashes, deaths, injuries and disabilities. The studies reporting these outcomes tend to have methodological limitations which reduce their usefulness for comparative purposes. Limitations include the absence of randomization for assigning subjects to intervention and control groups (*220–223*), the absence of detailed data for control groups (*221*), or the lack of a control group (*224*).

A systematic review (*218*), including 15 randomized controlled trials that measured the effectiveness of programmes of safety education for pedestrians, found:

- There was a lack of good evidence for adults, particularly in the case of elderly people.
- There was a lack of good evidence from low-income and middle-income countries.
- The quality of the studies was fairly poor, even in randomized controlled studies.
- The variety of intervention models and of methods of measuring outcomes made comparisons between studies difficult.
- Only surrogate outcomes were reported.
- While a change in knowledge and attitudes in children was confirmed, the size of the measured effect varied considerably.
- A change in behaviour was found in children, but not in all studies, and the size of the effect was influenced by the method of measuring, as well as by the context, such as whether a child was alone or with other children.
- The effect of education on the risk of a pedestrian incurring an injury remains uncertain.

Overall, the effect of safety education of pedestrians on behaviour varied considerably. Knowledge of pedestrian safety in children can translate into changed attitudes and even into appropriate forms of behaviour, but there is uncertainty about the extent to which the observed behavioural changes persist over time. There is no evidence that observed behaviour is causally related to the risk of occurrence of pedestrian injury. If it is, though, there is no reliable information about the size of the effect of pedestrian behaviour on the frequency of pedestrian injuries. Reliable scientific information on the effectiveness of educational approaches to pedestrian safety in low-income and middle-income countries is lacking. Also needing more research is the effectiveness of educational approaches in all countries with elderly pedestrians.

injured in road crashes are dealt with following a crash crucially determines their chances and the quality of survival.

A study in high-income countries found that about 50% of deaths from road traffic crashes occurred within minutes, either at the scene or while in transit to hospital. For those patients taken to hospital, around 15% of deaths occurred within the first four hours after the crash, but a much greater proportion, around 35%, occurred after four hours (*225*). In reality, therefore, there is not so much a "golden hour" in which interventions have to take place (*226*) as a chain of opportunities for intervening across a longer timescale. This chain involves bystanders at the scene of the crash, emergency rescue, access to the emergency care system, and trauma care and rehabilitation.

Pre-hospital care

As already pointed out in the previous chapter, the vast majority of road traffic deaths in low-income and middle-income countries occur in the pre-hospital phase (*227*). In Malaysia, for instance, 72% of motorcycle deaths occur during this phase (*228*). At least half of all trauma deaths in high-income countries are pre-hospital deaths (*225, 227*). A number of options exist for improving the quality of pre-hospital care. Even where these options are cheap, they are frequently not taken up to sufficient extent (*229*).

Role of lay bystanders

Those who are present or who arrive first at the scene of a crash can play an important role in various ways, including:

— contacting the emergency services, or calling for other forms of help;
— helping to put out any fire;
— taking action to secure the scene (e.g. preventing further crashes, preventing harm to rescuers and bystanders, controlling the crowd gathered at the scene);
— applying first aid.

Many deaths from airway obstruction or external haemorrhage could be avoided by lay bystanders trained in first aid (*230*).

In low-income and some middle-income countries, rescue by ambulance occurs in the minority of cases and assistance from a lay bystander is the main source of health care for the victims. In Ghana, for example, the majority of injured patients who reach hospital do so by means of some form of commercial vehicle (*227, 231*). It has been suggested that basic first-aid training for commercial drivers might be helpful (*227*), though it has not been scientifically established whether such a measure would decrease pre-hospital mortality (*229*).

A pilot project on pre-hospital care training was conducted in Cambodia and northern Iraq, in areas with a high density of landmines where people were frequently injured (*232*). The first stage of the project involved giving 5000 lay people a basic two-day training course in first aid. These people would be "first responders" in landmine explosions. In the second stage, paramedics were given 450 hours of formal training. A rigorous evaluation was conducted of the effects of the project on landmine-related injuries in the two areas, using an injury surveillance system. Among those severely injured in the areas covered by the project, the mortality rate fell from 40% before the project to 9% afterwards. The project relied on training and some basic supplies and equipment, but did not provide vehicles, such as formal ambulances. Transportation continued to be provided by the existing system of public and private vehicles in each area.

Similar pilot programmes have taken place, or are being conducted, involving training for lay "first responders" or others who are not health care professionals but who might have occasion to come upon injured people on a regular basis. They include training for police in Uganda and for the lay public generally in India, though evaluations have not yet been published of these two programmes.

Programmes providing first-aid training to the lay public, either generally or to particular population groups – such as the police, commercial drivers or village health workers – should follow certain principles to help strengthen their impact. For instance, such programmes should:

— base the contents of their training on epide-

miological patterns in the particular area in which they are to operate;
— standardize training internationally;
— monitor the results;
— plan periodic refresher courses, using results of monitoring to modify the contents of the training.

Access to the emergency medical system

In low-income countries, the development of the emergency medical system is limited by economic constraints and by the restricted availability of telecommunications. While some low-income countries have started rudimentary ambulance services in urban areas, they are still the exception as far as most of sub-Saharan Africa and southern Asia is concerned (*229*). International reviews have urged caution in transferring emergency medical systems from high-income countries to low-income countries, questioning whether such actions represent the best use of scarce resources. Another concern is the lack of conclusive evidence on the benefits of some Advanced Life Support measures commonly used in high-income areas, such as pre-hospital endotracheal intubation and intravenous fluid resuscitation (*233–235*). Further research is clearly needed on the effectiveness and cost-effectiveness of such more advanced measures. Research is equally called for on the role of Basic Life Support training in low-income countries – particularly in rural areas, where there is no formal emergency medical system and it might take days to reach professional medical care (*229*).

In high-income countries, access to the emergency medical system is almost always made by tele-phone, but the coverage and reliability of the telephone link varies between countries. The growth in the use of mobile telephones, even in low-income and middle-income countries, has radically improved emergency access to medical and other assistance. In many countries, there is a standard emergency telephone number that can be dialled for urgent assistance. Uniform codes for emergency assistance, for land telephones and mobile phones, should be set up in all regions of the world.

Emergency rescue services

Police and firefighters often arrive at the crash scene before personnel from the emergency medical service. Early intervention by firefighters and rescuers is critical where people are trapped in a vehicle, particularly if it is on fire or submerged under water. Firefighters and police need to be trained, therefore, in basic life support. There should be close cooperation between firefighters and other groups of rescuers, as well as between firefighters and health care providers (*225*).

As mentioned earlier, there are risks associated with ambulance transport, both for those transported by the ambulance as well as people in the street. Safety standards must therefore be established for transportation by ambulance – for instance, on the use of child restraints and adult seat-belts.

The hospital setting

There is growing understanding in high-income countries of the principal components of hospital trauma care and an awareness of what aspects require further research. Many improvements have taken place in trauma care over the last 30 years, largely as a result of new technology and improvements in organization (*236*). Clinical capabilities and staffing, equipment and supplies, and trauma care organization are all issues considered by medical experts to be of great importance (*225, 237*).

Human resources

Training for teams managing trauma care is vital. It is generally acknowledged that the standard for such training in high-income countries is the Advanced Trauma Life Support course of the American College of Surgeons (*225, 229, 238*). The applicability of this course to low-income and middle-income countries, though, has yet to be established.

The problems faced by low-income countries in relation to human resources, equipment and the organization of services have already been discussed. Though little has been documented on effective ways to deal with these problems, there is some evidence of successful practice (*229*). In Trinidad and Tobago, for instance, the introduction of the Advanced Trauma Life Support course for doctors and the Pre-Hospital Trauma Life Support course for paramedics, together with improved emergency equipment, led to improvements in trauma care and a decrease in trauma mortality, both in the field and in hospital (*239*).

South Africa (a middle-income country) also runs Advanced Trauma Life Support courses for doctors (*240*), though a cost–benefit analysis of this training has not been performed. Several low-income countries in Africa have adapted South Africa's programme to their own circumstances, which generally include a lack of high-tech equipment and practical difficulties in referring patients to higher levels of care (*236*).

Apart from short in-service training, there also needs to be more formal, in-depth training. This includes improving the trauma-related training received by doctors, nurses and other professionals, both in their basic education and in postgraduate training.

Physical resources

Many hospitals in low-income and middle-income countries lack important trauma-related equipment, some of which is not expensive.

In Ghana, for instance, as mentioned in the previous chapter, a survey of 11 rural hospitals found that none had chest tubes and only four had emergency airway equipment. Such equipment is vital for treating life-threatening chest injuries and airway obstruction, major preventable causes of death in trauma patients. All of it is cheap and much is reusable. The survey suggested that a lack of organization and planning, rather than restricted resources, was to blame (*241*). Similar deficiencies have been documented in other countries. In public hospitals in Kenya, shortages of oxygen, blood for transfusion, antiseptics, anaesthetics and intravenous fluids have been recorded (*242*). Research is urgently needed on this problem. It is important, too, to draw on relevant experience from other fields. National blood transfusion centres, for example, with their management of blood for transfusions – which involves recruiting suitable donors and collecting blood, screening donated blood for transfusion-transmissible infections, and ensuring that a safe blood supply is constantly available at places throughout the country.

Organization of trauma care

A prerequisite for high-quality trauma care in hospital emergency departments is the existence of a strategy for the planning, organization and provision of a national trauma system. There is considerable potential worldwide to upgrade arrangements for trauma care and improve training in trauma care at the primary health care level, in district hospitals and in tertiary care hospitals. International guidelines for this, based on research, need to be established.

The Essential Trauma Care Project is a collaborative effort between the WHO and the International Society of Surgery that aims to improve the planning and organization of trauma care worldwide (*243*). The project seeks to help individual counties, in developing their own trauma services, to:

- define a core of essential injury treatment services;
- define the human and physical resources necessary to assure such services in the best possible way, given particular economic and geographic contexts;
- develop administrative mechanisms to promote these and related resources on a national and international basis; such mechanisms will include specific training programmes, programmes to improve quality and hospital inspections.

While the goals of the Essential Trauma Care Project extend beyond the field of road safety, the success of the project can only be beneficial for crash-related trauma care.

Rehabilitation

For every person who dies in a road traffic crash, many more are left with permanent disabilities.

Rehabilitation services are an essential component of the comprehensive package of initial and post-hospital care of the injured. They help to minimize future functional disabilities and restore the injured person to an active life within society. The importance of early rehabilitation has been proved, though best practice in treatment programmes has yet to be identified (*225*). Most countries need to increase the capacity of their health care systems to provide adequate rehabilitation to survivors of road traffic crashes.

High-quality treatment and interventions for rehabilitation during the period of hospitalization immediately following an injury are of utmost importance, in order to prevent life-threatening complications related to immobilization. However, despite the best management, many people will still become disabled as a consequence of road traffic crashes. In low-income and middle-income countries, efforts should focus on capacity building and personnel training so as to improve the management of survivors of road traffic crashes in the acute phase, and thus prevent, as far as possible, the development of permanent disability.

Medical rehabilitation services involve professionals from a range of disciplines. These include specialists in physical medicine and rehabilitation, as well as in other medical or paramedical fields, such as orthopaedics, neurosurgery and general surgery, physical and occupational therapy, prosthetics and orthotics, psychology, neuropsychology, speech pathology and nursing. In every case, the recovery of both the patient's physical and mental health is paramount, as well as their ability to become independent again and participate in daily life.

Medical rehabilitation services also play a vital part in helping those living with disabilities to achieve independence and a good quality of life. Among other things, these services can provide mechanical aids that greatly assist affected individuals to be reintegrated into, and participate in, ordinary daily activities, including their work. Such aids, delivered through outpatient departments or outreach services to the home, are often essential in preventing further deterioration. In many countries, once acute management has been accomplished and mechanical aids provided, community-based rehabilitation remains the only realistic means of reintegrating the individual into society.

Research

Much of the research on the effectiveness and cost–benefits of interventions takes place in high-income countries. The development of national research capacity is thus an urgent need in many other parts of the world (*244, 245*). Experience from high-income countries shows the importance of having at least one – preferably independent – national organization receiving solid core funding that deals with road safety research.

Encouraging the development of professional expertise across a range of disciplines at national level, together with regional cooperation and exchange of information, have reaped much benefit in industrialized countries. Developing these mechanisms should be a priority where they do not exist. Among the many research-related needs for road injury prevention, the following are some of the more pressing:

- Better collection and analysis of data, so as to enable more reliable estimates to be made of the global burden of road traffic injuries, especially in low-income and middle-income countries. This includes mortality data, conforming to internationally-standardized definitions, and data on acute morbidity and long-term disability. There should also be more research to find low-cost methods of obtaining these data.
- Further data on the economic and social impacts of road traffic injuries, especially in low-income and middle-income countries. There is a considerable lack of economic analysis in the field of road injury prevention in these countries. The cost of injuries is not known empirically, neither are the cost nor cost-effectiveness of interventions.
- Studies demonstrating the effectiveness of specific interventions for injuries in low-income and middle-income countries.
- Design standards and guidelines for intercity roads carrying mixed traffic.

The following areas require particular research:

— how best to assess the effectiveness of packages of road safety measures combining different actions, such as area-wide traffic calming and urban design;

— the interaction between transport planning and urban and regional planning, and how these affect road safety;

— the design of roads and traffic management, taking into account traffic environments and

traffic mixes encountered in low-income and middle-income countries;
— how successfully various types of preventive measures can be transferred between countries with differing socioeconomic conditions and differing rates of motorization and traffic mixes.

Research in low-income and middle-income countries needs to be carried out on a regional basis towards developing the following:
— light, well-ventilated motorcycle helmets;
— safer bus and truck fronts;
— standards for motorcycle crash protection;
— the visibility and crash protection of indigenously-designed vehicles.

Improvements in post-impact care at an affordable cost are a priority area for the health sector. Equally important is research to better understand the mechanisms causing head injury and whiplash injury in road crashes, and treatments for these injuries. There is currently, for instance, no effective pharmacological treatment for head injury.

In all countries, further research is required into managing exposure to risk – the least-used injury prevention strategy. It is also essential to resolve the growing incompatibility in many places between smaller, lighter vehicles and larger, heavier ones.

Conclusion

Substantial research and development over the last 30 years have proved that a range of interventions exist to prevent road crashes and injury. The gap, though, between what is known to be effective and what is actually practised is often considerable. As with other areas of public health, road injury prevention requires effective management to put in place sustainable, evidence-based measures, overcoming obstacles to their implementation.

Good transport and land-use policies offer a means of reducing the exposure to risk for road crash injury. Safety-conscious planning and design of the road network can minimize the risk of crashes and crash injury. Crash-protective features on a vehicle can save lives and reduce injuries for road users, both inside and outside the vehicle. Compliance with key road safety rules can be significantly increased using a combination of legislation, enforcement of the laws, and information and education. The availability of good quality emergency care can save lives, and greatly reduce the severity and long-term consequences of road injuries.

A large proportion of road traffic injuries in low-income and middle-income countries occur among vulnerable road users. An important priority must therefore be to introduce a wide range of measures that give these road users greater protection. All the prevention strategies described in this report call for a wide mobilization of effort, at all levels, involving close collaboration across many disciplines and sectors, prominent among which is the health sector.

Despite many attempts to find and document examples of "good practice" in road safety in developing countries, such examples seem to be few. This chapter, therefore, remains slanted to a description of what has been successful in highly-motorized countries. This is not to say that the interventions presented in this chapter will not work in low-income or middle-income countries – indeed, many of them do. There needs, though, to be further testing of prevention strategies, to find ways to adapt them to local conditions – and not merely to adopt and apply them unchanged.

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