CHAPTER 3

Risk factors

Introduction

In road traffic, risk is a function of four elements. The first is the exposure – the amount of movement or travel within the system by different users or a given population density. The second is the underlying probability of a crash, given a particular exposure. The third is the probability of injury, given a crash. The fourth element is the outcome of injury. This situation is summarized in Figure 3.1.

FIGURE 3.1

The main risk factors for road traffic injuries

Factors influencing exposure to risk
- Economic factors, including social deprivation
- Demographic factors
- Land use planning practices which influence the length of a trip or travel mode choice
- Mixture of high-speed motorized traffic with vulnerable road users
- Insufficient attention to integration of road function with decisions about speed limits, road layout and design

Risk factors influencing crash involvement
- Inappropriate or excessive speed
- Presence of alcohol, medicinal or recreational drugs
- Fatigue
- Being a young male
- Being a vulnerable road user in urban and residential areas
- Travelling in darkness
- Vehicle factors – such as braking, handling and maintenance
- Defects in road design, layout and maintenance which can also lead to unsafe road user behaviour
- Inadequate visibility due to environmental factors (making it hard to detect vehicles and other road users)
- Poor road user eyesight

Risk factors influencing crash severity
- Human tolerance factors
- Inappropriate or excessive speed
- Seat-belts and child restraints not used
- Crash helmets not worn by users of two-wheeled vehicles
- Roadside objects not crash protective
- Insufficient vehicle crash protection for occupants and for those hit by vehicles
- Presence of alcohol and other drugs

Risk factors influencing severity of post-crash injuries
- Delay in detecting crash
- Presence of fire resulting from collision
- Leakage of hazardous materials
- Presence of alcohol and other drugs
- Difficulty rescuing and extracting people from vehicles
- Difficulty evacuating people from buses and coaches involved in crash
- Lack of appropriate pre-hospital care
- Lack of appropriate care in the hospital emergency rooms

Risk arises largely as a result of various factors, that include (*1*):

— human error within the traffic system;
— the size and nature of the kinetic energy of the impact to which people in the system are exposed as a result of errors;
— the tolerance of the individual to this impact;
— the quality and availability of emergency services and acute trauma care.

The human operator often adapts to changing conditions in ways that do not always serve safety. A single error can have life or death consequences. Behind road-user errors, there are natural limitations. These include vision in night traffic, the detection of targets in the periphery of the eye, the estimation of speed and distance, the processing of information by the brain, and other physiological factors associated with age and sex that have a bearing on crash risk. Also influencing human error are external factors such as the design of the road, the design of the vehicle, traffic rules and the enforcement of traffic rules (*2*). Sophisticated and quality-assured systems that combine human beings and machines, therefore, need to have an in-built tolerance of human error (*1*).

The tolerance of the human body to the physical forces released in crashes is limited. Injury is broadly related to the kinetic energy applied to the human frame. The energy involved in a collision varies as the square of the velocity, so that small increases in speed result in major increases in the risk of injury. The relationship between impact forces in crashes and the injuries that are sustained is known for a number of parts of the body and type of injury – for different categories of road user, as well as for different age groups. Biomechanical thresholds associated with age, sex and speed are reliable predictors of crash injury. For example, impact forces that produce a moderate injury in a robust 25-year-old male will result in a life-threatening injury if applied to a 65-year-old infirm female (*3*).

The main road injury problems are being sustained worldwide by people who make similar mistakes, share the same human tolerance to injury limits and have the same inherent behavioural limitations. While the problems are different both qualitatively and quantitatively, the main risk factors appear to be the same worldwide (*4,5*).

Traditionally, analysis of risk has examined the road user, vehicle and road environment separately. In this report, a systems framework, where interactions between different components are taken into account, is used. Such a systems-oriented approach has been necessary for significant progress in tackling road trauma to be made (*6*).

Factors influencing exposure to risk

Risk in road traffic arises out of a need to travel – to have access to work, for instance, or for education or leisure pursuits. A range of factors determines who uses different parts of the transport system, how it is used and why, and at what times (*7*).

While in practical terms it may not be possible completely to eliminate all risk, it is possible to reduce the exposure to risk of severe injury and to minimize its intensity and consequences (*1*).

Rapid motorization

Motor vehicles

One of the main factors contributing to the increase in global road crash injury is the growing number of motor vehicles.

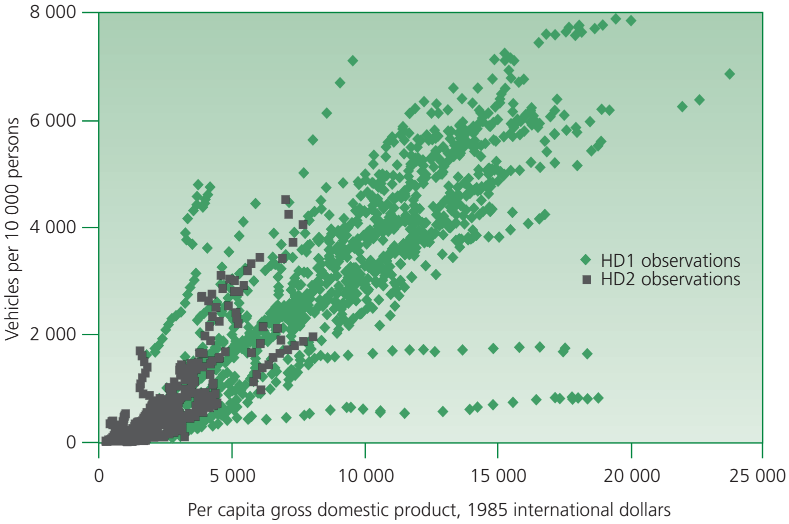
Since 1949, when Smeed (*8*) first demonstrated a relationship between fatality rates and motorization, several studies have shown a correlation between motor vehicle growth and the number of road crashes and injuries. While the motor vehicle and subsequent growth in the number of motor vehicles and road infrastructure has brought societal benefit, it has also led to societal cost to which road traffic injury contributes significantly. This explains why a number of studies are drawing attention to the need for careful consideration and planning of transport and mobility in view of the increasing motorization in different parts of the world (*9–11*).

Periods of economic prosperity tend to be associated with increasing mobility and demand for transport services. On the other hand, periods of economic decline lead to low generation of movement (*12*). In times of economic growth, traffic volumes increase, along with the number of crashes and injuries, and there are generally reductions in walking and cycling. Reductions in alcohol-related crashes have also been observed to coincide with periods of economic recession (*13*).

Motorization rate rises with income (*14*). In wealthier countries, there has been dramatic growth in the numbers of cars, but in many poorer countries the increases have been principally in motorcycles and minibuses. Some 80% of all cars are owned by 15% of the world's population, situated in North America, western Europe and Japan. Figure 3.2 and Table A.6 in the Statistical Annex both show that motorization is strongly correlated with income.

FIGURE 3.2

Motorization rate versus income[a]



[a] HDI is the United Nations Human Development Index. Countries with an HDI more than 0.8 are labelled as HD1 while those with a value less than 0.8 are denoted as HD2.

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In China, where the economy is experiencing rapid growth, the number of vehicles has more than quadrupled since 1990, to over 55 million. In Thailand, between 1987 and 1997, there was an almost four-fold increase in the number of registered motor vehicles, from 4.9 million to 17.7 million (*15*). In India, the number of four-wheeled motor vehicles increased by 23% to 4.5 million between 1990 and 1993. All of these figures are far below the rates of car ownership per capita in high-income countries (*16*). It is predicted that the motor vehicle numbers for countries of the Organisation for Economic Co-operation and Development (OECD) could increase up to 62% by the year 2015, to a total of 705 million (*14*).

Motor vehicle growth in low-income countries is taking place against a background of associated problems. Only a small number of people in these countries can afford cars, while the costs of roads, parking spaces, air pollution and road traffic injuries are borne by the whole society (*9*). Despite the rapid growth in motorized traffic, most families in low-income and middle-income countries are unlikely to own a car within the next 25 years (*5*). In terms of exposure to risk, the main modes of travel in these countries in the foreseeable future are likely to remain walking, cycling and public transport. This emphasizes the importance of planning for the needs of these road users, who, as was seen in Chapter 2, bear a high proportion of the burden of road traffic injuries.

The case of reunification in Germany provides a good illustration of how economic factors can influence crash injury. Here, overnight, many people suddenly experienced a surge in affluence and access to previously unavailable cars. In the two years following reunification, the number of cars that were bought and the total distance travelled by cars increased by over 40%. At the same time, between 1989 and 1991, there was a four-fold increase in death rates for car occupants, with an eleven-fold increase for those aged 18–20 years. The overall death rate in road crashes in this period nearly doubled, from 4 per 100 000 population in 1989 to 8 per 100 000 in 1991 (*17*). Other countries where motor vehicle growth has been shown to be associated with an increase in road traffic injuries are the Czech Republic, Hungary and Poland (*11, 18*). In Poland, for every additional 1000 cars purchased between 1989 and 1991, an additional 1.8 traffic fatalities and 27 people injured in crashes were recorded (*11*).

Traffic volume is a particularly important risk factor for injuries among child pedestrians. Roberts et al. have shown that when traffic volumes fall there is a reduction in child pedestrian death rates (*19, 20*).

Buses and trucks are a major mode of travel in low-income and middle-income countries. High volumes of passengers being transported have an impact on the safety, not only of the passengers themselves, but also on vulnerable road users. In New Delhi, buses and trucks are involved in almost two thirds of crashes involving vulnerable road users, and these people make up over 75% of all road traffic deaths (*5*).

Motorized two-wheeled vehicles

Although the greatest growth rate in the number of motor vehicles is expected in Asian countries, most of the increase in vehicle fleets is likely to be in motorized two-wheeled vehicles and three-wheelers (*5*). In many such places, it is estimated that motorized two-wheelers will comprise between 40% and 70% of the total vehicle fleet.

In south-east Asia, there are several countries with a large proportion of two-wheeled and three-wheeled vehicles whose growth in numbers has been associated with a large rise in road traffic injuries. Examples are Cambodia (where 75% of all vehicles are motorized two-wheelers or motorized three-wheelers), the Lao People's Democratic Republic (79%), Malaysia (51%) and Viet Nam (95%). In Viet Nam, the number of motorcycles grew by 29% during 2001; at the same time road deaths rose by 37% (*21*). An increase in use of motorized two-wheelers in China, Province of Taiwan, where such vehicles comprise 65% of all registered motor vehicles, was also associated with increasing deaths and injuries (*22*).

In the United Kingdom, after a long-term downward trend in both motorized two-wheeler traffic and deaths related to their use, a resurgence of interest in these vehicles over the last few years has been accompanied by sharp increases in motorized two-wheeler deaths and serious injuries. The national level of deaths and serious injuries among users of motorized two-wheelers in 2001 was 21% above the average for 1994–1998 (*23*).

Like other motor vehicles, motorized two-wheelers also cause injuries to other road users. In low-income countries, where the majority of pedestrian impacts are with buses and cars, one hospital-based study in New Delhi found that 16% of injured pedestrians had been struck by motorized two-wheelers (*24*).

Non-motorized traffic

Non-motorized vehicles predominate in both rural and urban areas in some low-income and middle-income countries. In these countries, the proportion of road traffic injuries from non-motorized forms of travel varies according to the way motorized and non-motorized modes of travel are split (*11*). In Asia, however, motorcycles are dominant, which partly explains the high proportion of motorcycle fatalities and injuries. Generally speaking in developing countries, pedestrian and cyclist traffic has grown without accompanying improvements in facilities for these road users. The high number of pedestrian and cyclist casualties in these countries reflects not only their inherent vulnerability but also insufficient attention to their needs in policy-making (*11, 25, 26*).

Demographic factors

Different groups of people have different exposures to risk. As populations change over time, so the overall exposure of that population will change. Fluctuations in the relative sizes of different population groups will have a strong effect on the road traffic toll. For instance, in industrialized countries, young drivers and riders – at increased risk of involvement in road crashes – are currently overrepresented in casualty figures. Demographic changes, though, in these countries over the next 20–30 years will result in road users over 65 years of age becoming the largest group of road users. Their physical vulnerability, though, places them at high risk of fatal and serious injuries (*27*). In low-income countries, the expected demographic evolution suggests that younger road users will continue to be the predominant group involved in road crashes.

In some high-income countries, more than 20% of the population will be 65 years or above by 2030 (*28*). Despite the rising number of older people holding driving licences in such countries, their declining driving ability as well as possible financial constraints will mean that many of them will have to give up driving. In many low-income countries, older people may never have driven in the first place. Worldwide, a large proportion of older people will still be dependent on public transport or will walk. This illustrates the importance of providing safer and shorter pedestrian routes and safe and convenient public transport.

Transport, land use and road network planning

Planning decisions regarding transport, land use and road networks have significant effects on public health – as they affect the amount of air pollution by vehicles, the degree of physical exercise undertaken by individuals, and the volume of road traffic crashes and injuries.

The development of a network of roads – or indeed of other forms of transport, such as railways – has a profound effect on communities and individuals. It influences such things as economic activity, property prices, air and noise pollution, social deprivation and crime – in addition to health. Long commuting times degrade the quality of life and therefore health. Sedentary travel directly and adversely affects health (*29*).

In the absence of proper land-use planning, residential, commercial and industrial activity will evolve in a haphazard pattern, and road traffic will evolve similarly to meet the needs of these various activities. This is likely to produce heavy flows of traffic through residential areas, vehicles capable of high speed mixing with pedestrians, and heavy, long-distance commercial traffic using routes not designed for such vehicles. The consequent exposure to traffic injury can be high for car occupants, and even more so for vulnerable road users, such as pedestrians, cyclists and motorized two-wheeler users (*30*).

The mixed nature of road traffic in many low-income and middle-income countries – with pedestrians, bicycles, handcarts, mopeds, motorcycles, vans, cars, trucks and buses in different proportions – means that many of the technical aspects of planning, highway design, traffic engineering and traffic management need to be worked out locally, rather than being imported. For example, in many Asian cities, with some notable exceptions, the road network is used by at least seven categories of motorized and non-motorized vehicles, of varying widths and speeds, all sharing the road space. There is generally no effective channelling or segregation of the different categories, or speed control (*31*).

Where planning of land use does take place, it is often done with a view to creating efficient flows of traffic, resulting in major arterial, high-speed routes that cut off different urban sections, to the disadvantage of local residents. Environmental criteria – such as reductions in noise, pollution and visual intrusion – are also often employed in planning. Safety considerations are brought in much less often. When safety criteria are applied to land use planning, though, there is ample evidence of significant reductions in exposure to traffic injury (*29*).

Increased need for travel

All growing urban areas experience a movement of residents from the inner districts to the suburbs. Socioeconomic changes in many places are leading to a profusion of out-of-town supermarkets and shopping malls, with a consequent loss of local shops. Both of these phenomena generate increased traffic, less opportunity for travel by public transport, and increased exposure to risk.

These factors need to be better recognized and evaluated in planning processes. This applies not only to developed countries but also to developing countries, some of which contain rapidly-growing megacities, with their significant but undocumented changes in patterns of wealth and living space.

Choice of less safe forms of travel

Of the four main modes of travel, road travel scores by far the highest risk in most countries – using almost any measure of exposure – compared with rail, air and marine travel (*32, 33*).

Within the mode of road travel, major variations in risk exist between pedestrians, cyclists, riders of motorized two-wheelers, car occupants, and bus and truck passengers. The risks for these road users also vary greatly according to the traffic mix and hence vary greatly from country to country. In general, in high-income countries, riders of motorized two-wheelers have the highest levels of risk.

In European Union countries, the risk of death for motorized two-wheeler users is 20 times that of car occupants (see Table 3.1). Travelling by car is some 7–9 times safer than cycling or walking, but car occupants are still 10 times less safe than bus occupants. All these relative risks are calculated on the basis of distance travelled. Even when the risks of walking or cycling before or after a train or bus trip are taken into account, travel by public transport is still safer than car travel, when the collective safety of all users is considered (*32*).

TABLE 3.1

Deaths per 100 million passenger-kilometres versus passenger-travel hours in European Union countries for the period 2001–2002

	Deaths per 100 million passenger-kilometres[a]	Deaths per 100 million passenger-travel hours[b]
Roads (total)	0.95	28
Powered two-wheelers	13.8	440
Foot	6.4	75
Cycle	5.4	25
Car	0.7	25
Bus and coach	0.07	2
Ferry	0.25	16
Air (civil aviation)	0.035	8
Rail	0.035	2

[a] Passenger-kilometres is the total distance covered by all the individuals travelling on that mode.

[b] Passenger-travel hours is the total time spent by all the individuals travelling on that mode.

Source: reproduced from reference *32*, with minor editorial amendments, with the permission of the publisher.

The choice of mode of travel is greatly influenced by the climate. Extremes of temperature severely limit cycling and walking.

As Table 3.2 shows, the traffic crash cost of injuries among motorized two-wheeler users is also higher than for any other mode (*33*).

TABLE 3.2

Traffic crash cost per passenger-kilometres

Mode of transport	Cost per passenger- km (in US$)
Commercial aviation	0.01
Rail	0.06
Bus	0.23
Car	0.28
General aviation	0.39
Motorcycle	1.52

Source: reproduced from reference *33*, with the permission of the publisher.

The level and mix of motorized two-wheeler use have long been volatile features of road use, both for urban commuting and for rural recreation (*34*). In this context, if the number of road injuries is to be minimized, care should be taken to avoid the adoption of policies which could encourage the growth of motorized two-wheeler traffic by giving advantages to motorized two-wheeler users.

A recent report by the organization Transport for London stated that one reason for providing motorized two-wheelers with exemption from the city's congestion charge scheme was their smaller contribution to congestion in central London. Transport for London suggested that there could be a small increase in motorized two-wheeler activity as a consequence of the new scheme, though it stated that distinguishing such a change from background trends could be difficult (*35*). When compared against trends over recent years for all other vehicle types, though, the relative share of trips undertaken by motorized two-wheelers was already increasing (*35*), and motorized two-wheeler users are a leading casualty group in the United Kingdom. By the end of 2002, deaths and serious injuries among motorized two-wheeler users in London were 31% above the 1994–1998 average (*36*). Thus if present trends continue, it seems unlikely that the target of a 40% reduction in motorcycle deaths by 2010 will be achieved.

Risk factors influencing crash involvement

Speed

The speed of motor vehicles is at the core of the road injury problem. Speed influences both crash risk and crash consequence.

"Excess speed" is defined as a vehicle exceeding the relevant speed limit; "inappropriate speed" refers to a vehicle travelling at a speed unsuitable for the prevailing road and traffic conditions. While speed limits only declare higher speeds to be illegal it remains for each driver and rider to decide the appropriate speed within the limit.

The speed drivers choose to travel at is influenced by many factors (see Table 3.3). Modern cars have high rates of acceleration and can easily reach very high speeds in short distances. The physical layout of the road and its surroundings can both encourage and discourage speed. Crash risk increases as speed increases, especially at road junctions and while overtaking – as road users underestimate the speed, and overestimate the distance, of an approaching vehicle.

TABLE 3.3

Examples of factors affecting drivers' choice of speed

Road and vehicle related	Traffic and environment related	Driver related
Road	Traffic	Age
Width	Density	Sex
Gradient	Composition	Reaction time
Alignment	Prevailing speed	Attitudes
Surroundings	Environment	Thrill-seeking
Layout	Weather	Risk acceptance
Markings	Surface condition	Hazard perception
Surface quality	Natural light	Alcohol level
Vehicle	Road lighting	Ownership of vehicle
Type	Signs	Circumstances of journey
Power/weight ratio	Speed limit	Occupancy of vehicle
Maximum speed	Enforcement	
Comfort		

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Crash risk

There is a large amount of evidence of a significant relationship between mean speed and crash risk:

- The probability of a crash involving an injury is proportional to the square of the speed. The probability of a serious crash is proportional to the cube of the speed. The probability of a fatal crash is related to the fourth power of the speed (*38, 39*).
- Empirical evidence from speed studies in various countries has shown that an increase of 1 km/h in mean traffic speed typically results in a 3% increase in the incidence of injury crashes (or an increase of 4–5% for fatal crashes), and a decrease of 1 km/h in mean traffic speed will result in a 3% decrease in the incidence of injury crashes (or a decrease of 4–5% for fatal crashes) (*40*).
- Taylor et al. (*41, 42*), in their study on different types of roads in the United Kingdom, concluded that for every 1 mile/h (1.6 km/h) reduction in average traffic speed, the highest reduction achievable in the volume of crashes was 6% (in the case of urban roads with low average speeds). These are typically busy main roads in towns with high levels of pedestrian activity, wide variations in speeds and high frequencies of crashes.
- A meta-analysis of 36 studies on speed limit changes showed, at levels above 50 km/h, a decrease of 2% in the number of crashes for every 1 km/h reduction in the average speed (*43*).
- A variation in speeds between different vehicles travelling at different speeds within the traffic stream is also associated with crash occurrence (*44*).
- A study of crashes within rural 60 km/h zones involving injuries to car occupants found that the relative risk of crash involvement doubles, or more, for each increase of 5 km/h of travelling speed above 60 km/h (*45*) (see Table 3.4). Travelling at 5 km/h above a road speed limit of 60 km/h results in an increase in the relative risk of being involved in a casualty crash that is comparable with having a blood alcohol concentration (BAC) of 0.05 gram per decilitre (g/dl) (*45*).

TABLE 3.4

Relative risks of involvement in a casualty crash for speed and alcohol

Speed (km/h)	Speed (relative risk[a])	Blood alcohol concentration (g/dl)	Blood alcohol concentration (relative risk[b])
60	1.0	0.00	1.0
65	2.0	0.05	1.8
70	4.2	0.08	3.2
75	10.6	0.12	7.1
80	31.8	0.21	30.4

[a] Relative to a sober driver travelling at the speed limit of 60 km/h.
[b] Relative to driving with a zero blood alcohol concentration.
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Severity of crash injuries

Speed has an exponentially detrimental effect on safety. As speeds increase, so do the number and severity of injuries. Studies show that the higher the impact speed, the greater the likelihood of serious and fatal injury:

- For car occupants, the severity of crash injury depends on the change of speed during the impact, usually denoted as Δv. As Δv increases from about 20 km/h to 100 km/h, the probability of fatal injuries increases from close to zero to almost 100% (*46*).
- The probability of serious injury for belted front-seat occupants is three times as great at 30 miles/h (48 km/h) and four times as great at 40 miles/h (64 km/h), compared with the risk at 20 miles/h (32 km/h) (*47*).
- For car occupants in a crash with an impact speed of 50 miles/h (80 km/h), the likelihood of death is 20 times what it would have been at an impact speed of 20 miles/h (32 km/h) (*48*).
- Pedestrians have a 90% chance of surviving car crashes at 30 km/h or below, but less than a 50% chance of surviving impacts at 45 km/h or above (*49, 50*) (see Figure 3.3).
- The probability of a pedestrian being killed rises by a factor of eight as the impact speed of the car increases from 30 km/h to 50 km/h (*51*).
- Older pedestrians are even more physically vulnerable as speeds increase (*52*) (see Figure 3.4).
- Excess and inappropriate speed contributes to around 30% of fatal crashes in high-income countries (*53*).

FIGURE 3.3

Pedestrian fatality risk as a function of the impact speed of a car

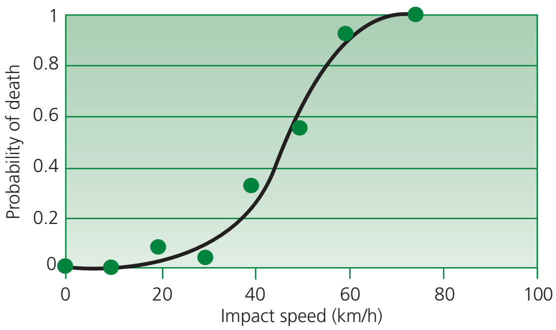

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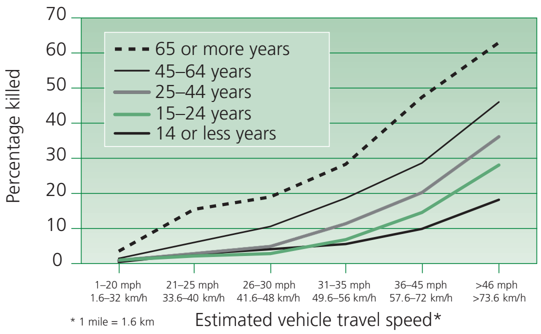
FIGURE 3.4

Fatal injury rates by vehicle speed and pedestrian age in Florida, 1993–1996 (pedestrians in single-vehicle crashes)



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In China, in 1999, speed was the main reported cause of road traffic crashes (*54*). Errors – such as loss of control of vehicle, speeding, misjudgement and improper overtaking – contributed to 44% of all police-reported crashes in Kenya (*55*). Speed was identified as the main contributory factor in 50% of road crashes in Ghana between 1998 and 2000 (*56*).

Speed has also been identified as an important factor in crashes involving commercial road transport and public passenger vehicles (*55, 57*). In South Africa, for instance, 50% of such crashes are related to speed (*57*). While in many high-income countries, there is increasing use of in-built mechanisms in trucks and buses to restrict speeds above a certain limit, such devices are frequently resisted in low-income and middle-income countries for commercial reasons, or else, if installed, are disabled by the operators. Commercial operations are often based on timetables that put pressure on drivers to speed. In many low-income and middle-income countries, the pay of bus drivers is related to ticket receipts, which encourages high speeds (*58*).

Everywhere, speed limits are widely flouted (*37*). At high speeds, environmental damage from exhaust emissions and traffic noise are greater at higher than at moderate speeds.

Figure 3.5 summarizes the main effects of speed on the risk of crashes and crash injury.

FIGURE 3.5

Summary of the effects of speed on crashes and crash injury

In highly-motorized countries, excessive and inappropriate speed is a major cause of around one in three of all fatal and serious crashes (53). Speed affects the risk of a crash occurring: the greater the speed, the less time there is to prevent a collision. At the same time, the greater the speed, the more severe the consequences, once a crash has occurred. Various studies have indicated that:

- An average increase in speed of 1 km/h is associated with a 3% higher risk of a crash involving an injury *(40, 41)*.
- In severe crashes, the increased risk is even greater. In such cases, an average increase in speed of 1 km/h leads to a 5% higher risk of serious or fatal injury *(40, 41)*.
- Travelling at 5 km/h above a road speed limit of 65 km/h results in an increase in the relative risk of being involved in a casualty crash that is comparable with having a BAC of 0.05 g/dl *(45)*.
- For car occupants in a crash with an impact speed of 50 miles/h (80 km/h), the likelihood of death is 20 times what it would have been at an impact speed of 20 miles/h (32 km/h) *(48)*.
- Pedestrians have a 90% chance of surviving car crashes at 30km/h or below, but less than a 50% chance of surviving impacts at 45 km/h or above *(50)*.
- The probability of a pedestrian being killed rises by a factor of 8 as the impact speed of the car increases from 30 km/h to 50 km/h *(51)*.

Pedestrians and cyclists

A disproportionately large number of pedestrian crashes and cyclist crashes occur in low-income countries (*4, 59–61*). Pedestrian casualties also represent a huge cost to society in industrialized nations (*62*), where the risks (measured in distance travelled or time spent travelling) are many more times higher for pedestrians and cyclists than for car users (*63*).

The crash risks incurred by pedestrians and cyclists result from a complex mix of factors. A fundamental factor in high-income countries is the fact that the modern traffic system is designed largely from the perspective of a motor vehicle user (*64*). Provision for pedestrians and cyclists in low-income countries is rudimentary or even non-existent.

The principal risk factor for unprotected road users is the mixing of unprotected people with motor vehicles capable of high speeds (*5, 60, 65*). The survival of unprotected users depends upon ensuring either that they are separated from the high speeds of motor vehicles or – in the more common situation of shared use of the road – that the vehicle speed at the point of collision is low enough to prevent serious injury on impact with crash-protective safer car fronts. The absence of adequate separate pedestrian and cyclist facilities, such as footpaths or cycle tracks, creates a high risk for these road users.

If separation is not possible, road management and vehicle speed management are essential. At low speeds, drivers have more time to react to unexpected events and to avoid collisions. At speeds of less than 30 km/h, pedestrians and cyclists can mix with motor vehicles in relative safety (*51*). Poor provision at crossings and junctions is also a feature of unsafe shared use. In urban areas, most fatal or serious cyclist crashes occur at junctions (*66*).

Other risk factors for pedestrians and cyclists include:

- poor street visibility;
- poor understanding on the part of pedestrians of road safety; in a study in Jordan, nearly half of children crossing a road did not check for oncoming traffic even once before or while crossing (*67*);
- alcohol impairment on the part of the cyclists or pedestrians;
- poor design of the fronts of cars (*65, 68–71*).

Young drivers and riders

Globally, road crash injury is a leading cause of death for young drivers and riders (*72*). Both young age and inexperience contribute to the high risk of these drivers and riders. Young drivers have a higher crash risk than older drivers (*73*). Being a young male is also predictive of crash involvement as a driver. It has been established in industrialized countries that men, especially young men in their first few years of driving, have higher rates of crash involvement than women, even when corrected for exposure factors (*74*).

In a study of injuries in Australia, Japan, Malaysia and Singapore, the highest injury risk was found among motorcyclists with a provisional licence, followed by those in their first year of riding (*75*).

The crash risks for teenage drivers are greater than those for any other comparable age group, with 16-year-old and 17-year-old drivers being at particular risk (*76*). Studies in developed countries indicate that the risks were particularly high during the 12 months after a full licence had been issued (*76*). The factors behind the elevated risk include:

- mobility patterns and vehicle characteristics (e.g. the vehicle is often borrowed);
- psychological characteristics, such as thrill-seeking and over-confidence;
- less tolerance of alcohol compared with older people;
- excess or inappropriate speed, the most common error among young drivers and riders.

Late-night driving is also a predictive factor for serious crashes among young drivers. For 16-year-old drivers, the late-night risk is three times the daytime risk (see also Box 3.1). While the night-time risks are greater for the youngest drivers, it is among drivers aged 20–44 years that the ratio of night-time driving risk to daytime risk is greatest – by a factor of four (*76*).

BOX 3.1

The human consequences of speed

Joelle Sleiman is 21 years old and lives in Marjeyoun in southern Lebanon. Her family – including her parents and two younger brothers – managed to survive the long civil war without serious incidents. On 16 August 2001, though, they were struck by tragedy when the two sons – Nicolas, 17 years, and Andy, 16 years – were involved in a car crash.

Nicolas loved cars and fast driving. Because of the lack of law enforcement in their area he was able to take the car out without a licence and drive at high speeds. He didn't listen to his parents' pleas not to drive.

On that terrible night, Joelle's mother was watching television late, waiting for the boys to come home. Instead, news of the crash arrived. Joelle and her parents rushed to the hospital, where they found Andy dead and Nicolas in a grave condition, not responding to treatment. They managed, with difficulty, to have Nicolas transferred to a hospital in Beirut, where he lay in a coma.

On the same day that Andy's funeral was held, the father was told that Nicolas's prospects were not promising. The family spent the next week praying for a miracle, but nothing could be done. Nicolas died one week after his brother. It eventually emerged that the boys were trying to avoid an unknown driver coming at them in the wrong direction, when they hit a wall.

When Joelle talks to other teenagers about speeding, they sometimes say to her, "It is up to us if we choose to die". They forget, Joelle points out, that they are not the only ones affected, that there are parents, brothers, sisters and close friends who love them. They should also think about that.

Losing her two brothers has completely changed Joelle's life. She now lives alone at home with her parents. She joined the Youth Association for Social Awareness (YASA), which has helped ease her inner pain. While she will not get her brothers back, she says that at least she can help other sisters avoid what she went through. Her work with YASA gives her pride, and she does it thinking of Andy and Nicolas.

The risk for young drivers increases exponentially as the number of passengers increases (*76*). One case–control study indicated that a third of all crashes involving young drivers might have been prevented if young drivers had been restricted to driving with no more than one passenger (*77*).

Alcohol

Crash risk

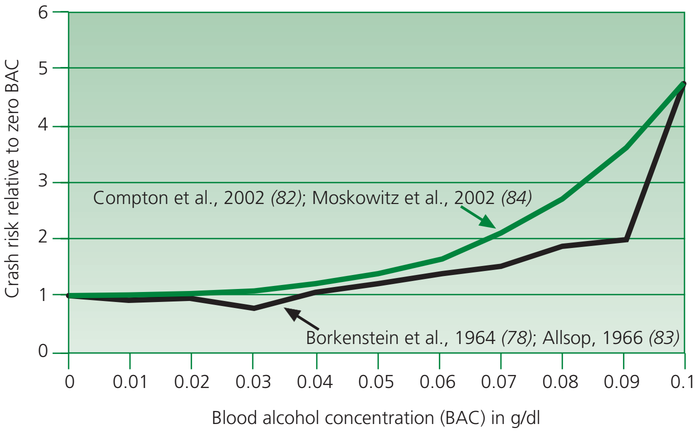
A case–control study carried out in Michigan, United States, in 1964, known as the Grand Rapids study (*78*), showed that drivers who had consumed alcohol had a higher risk of involvement in crashes than those with a zero BAC and that this risk increased rapidly with BAC. These results provided the basis for the future setting of legal blood alcohol limits and breath content limits in many countries around the world, typically at 0.08 g/dl.

In 1981, an Australian study found that the risk of crash involvement was 1.83 times greater at a BAC of 0.05 g/dl than at a BAC of zero (*79*). Re-analysis of the Grand Rapids data by Hurst et al. (*80*) also concluded that the risks associated with lower BAC levels were greater than originally thought. This information, together with findings from behavioural and experimental studies (*81*), provided a justification for many countries to reduce their legal BAC limits to 0.05 g/dl.

A major case–control study – using more robust research design and multivariate analytical techniques than the Grand Rapids study – has recently taken place to determine at what level of BAC an elevated crash risk begins (*82*). This study, involving 14 985 drivers, was conducted in the United States at Long Beach, California and Fort Lauderdale, Florida. The overall result was in agreement with previous studies showing increasing relative risk as levels of BAC increased (see Figure 3.6). The study found that the relative risk of crash involvement starts to increase significantly at a BAC level of 0.04 g/dl.

FIGURE 3.6

Relative risk of driver involvement in police-reported crashes



Source: references *78, 82–84*.

An Australian study of alcohol and motorcycle crashes found that having a BAC level greater than zero was associated with five times the risk relative to a zero BAC (*85*).

Age of drivers

The risk of a crash with alcohol varies with age and drinking experience. Zador estimated that crash rates of male drivers aged 16–20 years were at least three times the estimated crash rate of male drivers aged 25 years and above, for every BAC level (*86*). With few exceptions, the relative risk of being fatally injured in a single-vehicle crash was found to decrease with increasing driver age for every BAC level, for both men and women (*87*).

A study on drivers killed in road crashes estimated that teenage drivers had more than five times the risk of a crash compared with drivers aged 30 and above, at all levels of BAC. Drivers in the 20–29 years age group were estimated to have a three times higher risk than drivers aged 30 years and above, at all BAC levels (*88*). Teenage drivers with a BAC of 0.03 g/dl carrying two or more passengers were 34 times more at risk of a crash than drivers aged 30 years or more, with zero BAC, driving with one passenger (*88*).

Severity of crashes

A study in the United States of relative fatality risks at different BAC levels indicated that for single-vehicle crashes, each 0.02% increase in BAC level approximately doubled the risk of involvement in a fatal crash (*86*). A similar finding was reported in a New Zealand study that used a sample of crashes involving mainly single vehicles. The study calculated the risk for a driver of a fatal injury during the night-time, according to the number of passengers in the vehicle, the driver's age and the driver's BAC level (*88*).

A study in the United Kingdom, comparing data from roadside surveys with the corresponding ranges of BAC levels collected from coroners' reports, showed that the relative fatality risk increases exponentially with BAC, and that this risk was an order of magnitude larger than the risk of being involved in a crash with injuries (*89*).

The frequency of drinking and driving varies considerably around the world. Despite that, and despite the fact that there have been few studies in low-income countries, research indicates that the phenomenon continues to be a major risk factor in traffic crashes. After many years of decline, the rate of road traffic deaths involving alcohol has begun rising in several high-income countries (*90*). A review of surveys of drinking and driving levels in traffic in European Union countries found that alcohol was present in between 1% and 3% of drivers (*91*). Roadside surveys taken in Croatia indicated that over 4% of drivers were intoxicated (*92*). A Ghanaian study found that over 7% of drivers in a random breath test had BAC levels above 0.08 g/dl (*93*). In New Delhi, India, a study showed that a third of motorized two-wheeler riders taken to hospital admitted to driving under the influence of alcohol (*94*).

The effects of alcohol consumption on the risk of crashes and of crash injury are summarized in Figure 3.7.

FIGURE 3.7

Effects of alcohol on risk of crashes and on crash injury

- Drivers and motorcyclists with any level of BAC greater than zero are at higher risk of a crash than those whose BAC is zero.
- For the general driving population, as the BAC increases from zero, the risk of being involved in a crash starts to rise significantly at a BAC of 0.04 g/dl *(82)*.
- Inexperienced young adults driving with a BAC of 0.05 g/dl have 2.5 times the risk of a crash compared with more experienced drivers *(95)*.
- A study on drivers killed in road crashes estimated that teenage drivers had more than five times the risk of a crash compared with drivers aged 30 and above, at all levels of BAC. Drivers 20–29 years old were estimated to have three times the risk compared with drivers aged 30 years and above, at all BAC levels *(88)*.
- Teenage drivers with a BAC of 0.03 g/dl carrying two or more passengers were 34 times more at risk of a crash than drivers aged 30 years or more, with zero BAC, driving with one passenger *(88)*.
- If a BAC limit is fixed at 0.10 g/dl, this will result in three times the risk of a crash that exists with the most common limit, in high-income countries, of 0.05 g/dl. If the legal limit stands at 0.08 g/dl, there will still be twice the risk that there would be with a limit of 0.05 g/dl.
- Alcohol consumption by drivers puts pedestrians and riders of motorized two-wheelers at risk.

Research on the role of alcohol in crashes

Apart from in those countries where alcohol is prohibited, impairment by alcohol is likely to be an important factor in causing crashes and in exacerbating the consequences of crashes. Systematic surveillance, though, is not established in many countries (*96, 97*). In many low-income countries, the police often lack the means, in terms of human resources and equipment, to monitor routinely the level of alcohol in drivers, even where legal limits exist (*96*).

As Odero and Zwi (*97*) for low-income and middle-income countries and the European Transport Safety Council (ETSC) for Europe (*91*) have outlined, variable measurements; testing for different injury severities and different thresholds for BAC (where they exist), preclude a full comparison of excess alcohol levels between countries. Some studies refer to presence of any alcohol, others to alcohol over the legal limit, where such a limit exists.

From an investigation of studies conducted in low-income countries, it emerged that alcohol was present in between 33% and 69% of fatally-injured drivers, and in between 8% and 29% of drivers involved in crashes who were not fatally injured (*97*). Peden et al. (*98*) found that alcohol was a factor in around 29% of non-fatally-injured drivers, and in over 47% of fatally-injured drivers in South Africa. A later study found excess alcohol in over 52% of trauma patients involved in road crashes (*99*) (see also Box 3.2).

BOX 3.2

Alcohol-related road traffic deaths in South Africa

According to the South African national injury mortality surveillance system, there were 25 361 fatal injuries registered at 32 state mortuaries in 2001. This represents approximately 35% of all non-natural mortality in South Africa in that year. Transport-related deaths accounted for 27% of all the fatal injuries. Pedestrians were the group of road users most frequently killed (37.3%), followed by passengers of vehicles (17.4%), drivers (14.0%) and cyclists (3.1%).

Alcohol is a major risk factor for all types of fatal road traffic injury in South Africa. Tests for BAC were conducted on 2372 (or 34.6%) of the 6859 transport-related deaths. More than half (51.9%) of all transport-related deaths had elevated BAC, and of these positive cases, 91% recorded BAC levels of 0.05 g/dl or higher.

Pedestrians, followed by drivers, were most likely to be BAC-positive (see table below).

BOX 3.2 (continued)

	Blood alcohol concentration (g/dl)				
	Zero (%)	0.01–0.04 (%)	0.05–0.14 (%)	0.15–0.24 (%)	≥0.25 (%)
Pedestrians	37.5	5.4	12.0	20.5	24.7
Passengers	62.6	4.7	14.0	13.7	5.0
Drivers	48.2	5.3	18.2	18.8	9.5
Cyclists	61.3	3.2	15.1	14.0	6.5

Pedestrian fatalities also had the highest mean BAC levels (0.20 g/dl). Over 50% of drivers killed had elevated BAC levels and the mean level for drivers – 0.17 g/dl – was over three times the legal limit for driving, currently set in South Africa at 0.05 g/dl.

Research in the United States indicates that motorized two-wheeler riders have higher intoxication rates than motor vehicle drivers (*100*).

In Sweden, the Netherlands and the United Kingdom, the proportion of fatally-injured drivers with excess alcohol for each country is around 20%, though the legal limits in these countries differ considerably, being 0.02 g/dl, 0.05 g/dl and 0.08 g/dl, respectively (*101*).

Perception of risk of being caught with excess alcohol

Research has shown that the only consistently effective strategy for dealing with the problem of excess alcohol is to increase the perceived risk of being caught. Such a perception is considered a better deterrent than the severity or the swiftness of the penalty (*102*). With a few exceptions – including Australia and the Nordic countries – both the perception and the actual likelihood of being detected for excess alcohol are low in most countries, irrespective of personal income (*91*). In Thailand, over 80% of people surveyed considered their chances of being stopped by the police for BAC testing very low, while over 90% accepted the benefit of the law being enforced (*103*).

Pedestrians

Alcohol as a risk factor in pedestrian crashes has been well documented in high-income countries over several decades. Pedestrians impaired by alcohol, however, present a different order of risk to that of drinking drivers who pose more risks to themselves and others.

Clayton et al. established that for pedestrians there was a significantly higher risk of fatality relative to zero alcohol at BAC levels above 0.1 g/dl (*104*).

A review of Australian studies of alcohol involvement in pedestrian crashes showed that 20–30% of pedestrian casualties had a BAC level in excess of 0.15 g/dl, with alcohol involvement being greater among fatalities (*105*). Peden et al. (*98*) found that alcohol was a factor in over 61% of fatally-injured pedestrians in South Africa. A recent study in the United Kingdom concluded that 48% of pedestrians killed in road traffic collisions had been drinking, and that 39% of fatalities were over the legal BAC limit for driving (*106*). The proportion of male and female injured pedestrians consuming alcohol had increased by a third in the 16–19 years age group, when compared with findings from an earlier study conducted in 1985–1989 (*107*).

Medicinal and recreational drugs

While the contribution of alcohol to road crashes is much greater than that of any other drug, any medication or drug that affects the central nervous system has the potential to impair drivers (*108*). The effects, though, of both medicinal and recreational drugs on driving performance and crash involvement are much less well understood than those of alcohol, especially for low-income and middle-income countries. Determining the relationship between dose levels of drugs and increased crash risk is a complex matter. There exists a range of problems that make any interpretation of the relationship between drug levels (however measured) and driving safety extremely difficult, including the following:

- Most drugs, unlike alcohol, do not exhibit a simple relationship between drug blood-content and level of impairment (*109, 110*).
- Drugs within a particular category (e.g. antidepressants) can vary widely in their influence on behaviours, such as the distance a driver can brake in.
- Medically-impaired drivers may be safer driving with their drugs than without them, as in the case, for example, of schizophrenic patients with antipsychotic drugs (*111*).
- There are large individual differences in response to particular drugs.
- The short-term effects of certain drugs may differ from long-term effects (*112*).
- Many drugs are currently being used and several are often taken at the same time. Combinations of drugs may have synergistic effects (e.g. codeine and antipsychotic drugs with alcohol) or antagonistic effects. The number of possible interactions is great (*65, 113*).

Currently, there is no strong evidence that the use of drugs and driving constitutes a significant road crash risk. However, there is evidence for the increasing use among drivers of many psychoactive drugs, both medicinal and recreational, often in conjunction with alcohol (*114, 115*). This is an issue that needs urgent research.

Although studies support the notion that cannabis induces impairment (*109*), and in some countries there is a growing incidence of cannabis found in the blood of fatally-injured drivers, the evidence for its causal relationship with road traffic crashes remains undecided (*109, 116, 117*). A recent case–control study in France, though, found a higher prevalence of alcohol, cannabis and a combination of the two in blood samples from drivers involved in road crashes than in those from controls (*118*). A study in the United Kingdom also suggested a strong relationship between use of alcohol and cannabis together, and a clear reduction in driver capability following their use, compared with control data (*119*).

What is known suggests that drug use is a significant factor in some cultures but inadequate knowledge precludes quantifying the levels of risk at present. The availability and reliability of blood-screening procedures and confirmation tests for measuring alcohol and drug levels are problems for most low-income and middle-income countries. There is also the concern in high-income countries about screening for cannabis, since the substance can remain in the bloodstream for up to three weeks – hence making any attempt to link its use with driver impairment in a particular case exceptionally difficult.

Driver fatigue

Fatigue or sleepiness is associated with a range of factors (*120*) (see Table 3.5), including long-distance

TABLE 3.5

Factors that predispose a driver to fatigue

Drivers at risk of fatigue	Temporal factors causing fatigue	Environmental factors in fatigue	Sleep-related factors
Young drivers (up to 25 years)	Driving between 02.00 and 05.00	Driving in remote areas with featureless terrain	Driving with sleep debt
Drivers over 50 years	More than 16 hours of wakefulness before trip	Monotonous roads	Driving with a sleep-related condition
Males	Long work period before trip	Main arterial roads	Driving when normally asleep
Shift workers	Long time since start of trip	Long-haul driving	Drivers disposed to nodding off
Those for whom driving is part of job	Irregular shift work before trip	Unexpected demands, breakdowns, etc.	Driving after poor-quality sleep
Those with medical conditions (such as narcolepsy)	Driving after successive nights of shift work	Extreme climatic conditions	
After consuming alcohol	Driving under time pressure	Driving an unfamiliar route	
Driving after inadequate rest and sleep	Some drivers are drowsy in the afternoon		

Source: reproduced from reference *120*, with minor editorial amendments, with the permission of the author.

driving, sleep deprivation and the disruption of circadian rhythms. Three high-risk groups have been identified (*121*):

- young people, particularly males, aged 16–29 years;
- shift workers whose sleep is disrupted by working at night or working long, irregular hours;
- people with untreated sleep apnoea syndrome or narcolepsy.

Estimates of the proportion of car crashes attributable to driver sleepiness vary, depending on the type of study and the quality of data. A population-based case–control study in New Zealand found that factors that substantially increased the risk of a fatal crash or a crash with serious injuries were:

- driving while feeling sleepy;
- driving after less than five hours of sleep in the preceding 24 hours;
- driving between 02:00 and 05:00.

The study concluded that a reduction in all three of these behaviours could reduce the incidence of crashes involving injury by up to 19% (*122*).

Surveys of commercial and public road transport in developing countries have revealed that transport owners, in pursuit of increased profits, frequently force their drivers to drive at excessive speeds, to work unduly long hours and to work when exhausted (*58, 59, 123*).

Studies by the National Transportation Safety Board (NTSB) in the United States found that 52% of 107 single-vehicle crashes involving heavy trucks were fatigue-related and that in nearly 18% of the cases, the drivers admitted to having fallen asleep. The United States Department of Transportation's investigations into fatigue in the 1990s showed that fatigue was a factor in about 30% of fatal crashes involving heavy commercial transport (*124–126*).

In Europe, studies have been less comprehensive, and have often involved retrospective accounts that were likely to underestimate the impact of fatigue. These limitations notwithstanding, research from some European countries suggests that driver fatigue is a significant factor in approximately 20% of commercial transport crashes. The results from a range of surveys show that more than a half of long-haul drivers have at some time fallen asleep at the wheel (*127*).

Peak levels of fatigue-related crashes at night are often 10 times higher than daytime levels. Research in France on the working hours and habits of truck drivers (*128*) showed that their risk of crashes related to fatigue increased when:

- they were driving at night;
- the length of their working day had increased;
- they were working irregular hours.

Hand-held mobile telephones

The number of hand-held mobile telephones has increased rapidly in many high-income countries – in the United States, for example, from 500 000 in 1985 to over 120 million in 2001. Europe has also seen sharp increases in their number (*129*).

The use of hand-held mobile telephones can adversely affect driver behaviour – as regards physical as well as perceptual and decision-making tasks. The process of dialling influences a driver's ability to keep to the course on the road (*130*). Results of studies on distraction and mental load show that driver reaction times are increased by 0.5–1.5 seconds when talking into a mobile telephone (*131, 132*).

Studies have shown that driver performance is particularly affected in maintaining the correct lane position and the headway between two vehicles travelling one behind the other, in keeping to an appropriate speed, and in judging and accepting safe gaps in the traffic (*130, 131, 133, 134*). There is also some evidence from studies that drivers who use mobile telephones while driving face a risk of a crash four times higher than those who do not use them (*135*). Almost a half of drivers, though, involved in a crash used a mobile telephone to call for help (*135*). To date, at least 35 countries or territories have banned the use of hand-held mobile telephones while driving. While the use of hands-free telephones can also distract drivers, the current evidence suggests that the effect is less than that for hand-held telephones (*129*).

Inadequate visibility

To see and be seen is a fundamental prerequisite for the safety of all road users. Detailed studies in Australia, Germany and Japan have shown that visual errors play a very important role in the cause of crashes (*136*).

In highly-motorized countries, inadequate visibility plays a key role in three types of crashes (*137*):

— a moving vehicle running into the rear or side of a slowly moving or stationary vehicle located ahead on the roadway, at night-time;
— angled collisions or head-on collisions in daytime;
— rear-end collisions in fog, in daytime and at night.

In low-income and middle-income countries, the phenomenon of pedestrians and vehicles not being properly visible is frequently a serious problem. In these places, there are fewer roads with adequate illumination and some may not be lit at all. In addition, it is more common for large numbers of bicycles and other vehicles to have no lights and for road space to be shared by fast-moving and slow-moving road users.

Cars and trucks

An analysis of crashes in the state of Victoria, Australia, suggests that not being sufficiently visible is a factor in 65% of crashes between cars and motorized two-wheelers and the sole cause in 21% of them (*138*). A meta-analysis of the effect of using daytime running lights found a 10–15% reduction in daytime crashes involving more than one party. A few countries currently require the fitting and use of daytime running lights (*139*).

Research in Germany has shown that nearly 5% of severe truck crashes can be traced back to poor visibility of the truck or its trailer at night. In these cases, car drivers failed to recognize trucks turning off the road, turning around or driving ahead of them (*140*).

A number of crashes involve drivers who fail to see other road users in the blind spots that exist in the area immediately around their vehicles. When larger vehicles such as trucks or buses are involved, these crashes frequently lead to serious injuries or even fatalities among vulnerable road users, such as pedestrians, cyclists or drivers of motorized two-wheelers (*141*).

Motorized two-wheelers

Motorized two-wheelers, because of their size and shape, are less easy to see than other motor vehicles and have poor visibility in daytime (*142*). A study in Malaysia found that most motorcycle crashes were in daytime and that around two-thirds of the riders involved had the right of way (*143*). Motorized two-wheelers that use daytime running lights have a crash rate about 10–29% lower than those that do not (*66, 144*).

Pedestrians and cyclists

In low-income countries, the mix of motorized and non-motorized traffic, together with frequent poor lighting, leads to a high risk for unprotected users if they are not seen by traffic. Lack of access to retro-reflective equipment, absence of bicycle lamp fitment, and use of darkly coloured bicycle helmets exacerbate already unsafe conditions. A review of European in-depth research found that one third of pedestrian casualties had difficulty in seeing the striking vehicle. Similarly, two fifths of drivers had difficulty in seeing the pedestrian (*63*). The more conspicuous a particular motor vehicle is to all other road users, and the more visible the other road users are to the particular driver, then the greater the opportunity of avoiding a collision. More than 30% of bicycle crashes in the Netherlands occurring at night or in twilight could have been avoided, it is estimated, if bicycle lighting had been used (*145*).

Road-related factors

Road crashes tend not to be evenly distributed throughout the network. They occur in clusters at single sites, along particular sections of road, or scattered across whole residential neighbourhoods, especially in areas of social deprivation (*146*). While road engineering can greatly help in reducing the frequency and severity of road traffic crashes, poor engineering can contribute to crashes. The road network has an effect on crash risk because it determines how road users perceive their environment and provides instructions for road users, through signs and traffic controls, on what they should be doing. Many traffic management and road safety engineering measures work through their influence on human behaviour (*6*).

Negative road engineering factors include those where a road defect directly triggers a crash, where some element of the road environment misleads a road user and thereby creates error, or where some feasible physical alteration to the road that would have made the crash less likely has not been made (*147*).

In the planning, design and maintenance of the road network, four particular elements affecting road safety have been identified (*148*). These elements are:

— safety-awareness in the planning of new road networks;
— the incorporation of safety features in the design of new roads;
— safety improvements to existing roads;
— remedial action at high-risk crash sites.

The absence of any of these elements, discussed below, are risk factors for crashes.

Inattention to safety in planning new road networks

As already mentioned, crash risks in road networks are frequently increased by the existence of unnecessary motorized travel, by policies encouraging travel by less safe modes, and by the creation of unsafe mixes of travel (*5*).

Specific situations related to road planning that are risk factors for crashes include (*5, 148*):

— through-traffic passing through residential areas;
— conflicts between pedestrians and vehicles near schools located on busy roads;
— lack of segregation of pedestrians and high-speed traffic;
— lack of median barriers to prevent dangerous overtaking on single-carriageway roads;
— lack of barriers to prevent pedestrian access onto high-speed dual-carriageway roads.

The growth in urbanization and in the number of motorized vehicles in many low-income and middle-income countries has not been accompanied by adequate attention to road design.

Inattention to safety in designing roads

Where road layouts are self-explanatory to their users – through the use of markings, signs and physically self-enforcing measures to reduce speed – engineering can have a beneficial influence on behaviour. Engineering design, though, can often have negative influences on behaviour – when there is incompatibility between the function of the roads, their layout and their use, this creates risk for road users.

Uncertainty among road users about the layout of roads – through the absence of clear and unambiguous markings and signs – is a particular risk factor for crashes. Similarly, the lack of self-enforcing measures to reduce speed will increase the risk.

Straight, unmarked single-carriageway roads encourage drivers to speed. Other risk factors are the poor design and control of junctions and insufficient lighting.

Safety defects in existing roads

Defects contributing to crash risk can appear in road designs, especially if they have not been subject to a safety audit by experienced safety personnel. Such defects are frequently caused by the poor design of junctions or by design that allows for large differences in the speed and the mass of vehicles and in the direction of travel.

Bad road surface conditions are a particular risk factor for users of motorized two-wheelers. Often, where there is no safety impact study to assess the effects of a new road scheme on the existing network, a new road scheme can have an adverse impact on large areas.

Lack of remedial action at high-risk crash sites

Large numbers of high-risk crash sites exist everywhere, located either at isolated spots or grouped along particular stretches of road. Many of them are well-known and documented. Some 145 dangerous locations, for example, have been identified on Kenya's main rural road network (*149*). If such sites are not dealt with, promptly and systematically, there will be a great risk of further crashes.

A survey of 12 European Union countries found that many of them lacked comprehensive remedial programmes for high-risk sites (*147*). The survey showed that:

— only seven countries reported having a formal policy;
— only six had national guidelines or manuals;
— only five reported taking specific steps to stimulate remedial schemes;
— only three reported having a separate national budget;
— only three reported that evaluations were standard practice in applying remedial schemes.

Vehicle-related risk factors

While vehicle design can have considerable influence on crash injuries, its contribution to crashes, through vehicle defects, is generally around 3% in high-income countries (*150*), about 5% in Kenya (*4*) and 3% in South Africa (*151*).

Though periodic vehicle inspections have not been found useful in reducing injury crashes, inspections and checks for overloading and safety-related maintenance for larger commercial vehicles and buses could be important for vehicles more than 12 years old (*152*).

While there is in general no evidence that periodic motor vehicle inspections reduce crash rates, the exception is in the field of commercial vehicles, where defective brakes on large trucks have been shown to be a risk factor (*153*).

Risk factors influencing injury severity

Well-established risk factors that contribute to the severity of a crash include:
— inadequate in-vehicle crash protection;
— inadequate roadside protection;
— the non-use of protective devices in vehicles;
— the non-use of protective crash helmets;
— excessive and inappropriate speed;
— the presence of alcohol.

Lack of in-vehicle crash protection

In the past decade, the crashworthiness of private cars for their occupants has improved considerably in many high-income countries, though there is considerable room for further improvement (*53, 71, 154, 155*).

In low-income countries, the regulation of motor vehicle safety standards is not as systematic as in high-income countries. Many engineering advances that are found in vehicles available in high-income countries are not standard fittings in vehicles in low-income countries (*4*). In addition, the majority of road casualties in low-income countries occur outside the car, with those affected being pedestrians, cyclists, motorized two-wheeled vehicle riders or passengers in buses and trucks. As yet, there are no requirements to protect vulnerable road users by means of crash-worthy designs for the fronts of cars or buses (*61*).

Car occupants

The main injury risks for car occupants arise from the way vehicles interact with each other and with the roadside in frontal and side-impact crashes. In fatal and serious crashes, head, chest and abdominal injuries are predominant. Among injuries that cause disablement, those to the legs and neck are important. Determinants for the degree of severity of injuries include:
— contact by occupant with the car's interior, exacerbated by intrusion into the passenger compartment caused by the colliding vehicle or object;
— mismatch in terms of size and weight between vehicles involved in a crash;
— ejection from the vehicle;
— inadequate vehicle safety standards.

The European Commission has stated that if all cars were designed to be equal in standard to the best car currently available in each class, then an estimated 50% of all fatal and disabling injuries could be avoided (*53*).

The relationship between vehicle age and risk of a car crash with injury has recently been investigated. The study showed that occupants in cars manufactured before 1984 have approximately three times the risk of a car crash injury compared with occupants of newer cars (*156*).

Pedestrians

Crashes between vehicles and pedestrians are responsible for more than a third of all traffic-related deaths and injuries worldwide (*62*). Compared with vehicle occupant casualties, pedestrians sustain more multiple injuries, with higher injury severity scores and higher mortality rates (*157*).

Research in Europe suggests that two thirds of all fatally-injured pedestrians are hit by the front of a car; 11% are hit by other parts of a car. Impacts with all other types of vehicle account for the remaining 23% of pedestrian fatalities (*154*). In many low-income and middle-income countries, buses and trucks are also a major source of injury through impact for pedestrians, bicyclists and motorized two-wheeler riders. In India, in the cities and on rural highways, buses and trucks are involved in more than 50% of the crashes affecting pedestrians (*158*). The distribution of different vehicle types involved in pedestrian crashes in Ghana, shown in Table 3.6, is fairly typical for low-income countries. In Ghana, car-to-pedestrian impacts are the leading cause of pedestrian death and injury, followed by collisions of buses or minibuses with pedestrians.

TABLE 3.6

Frequency of involvement of different vehicles in pedestrian crashes and fatalities in Ghana, 1998–2000

Vehicle type	Percentage involvement in all crashes	Percentage involvement in fatal crashes
Cars/taxis	54.0	37.8
Bicycle	5.2	0.8
Motorcycle	2.8	2.1
Bus/minibus	23.4	31.8
Heavy goods vehicle	7.3	18.6
Pick-up trucks	6.4	7.6
Others	0.9	1.3

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

There are usually two phases in car-to-pedestrian collisions. The first and most severe phase consists of multiple impacts with different parts of the car front. The second phase is contact with the road surface, where injuries are generally minor (*159*).

The most frequent causes of serious and fatal pedestrian injuries in collisions with cars stem from impacts between (*160*):

— the head of the pedestrian and the whole area of the car bonnet top and windscreen frame;
— the pelvis or the abdomen of adults and the bonnet edge;
— the abdomen or chest of children or the head of small children and the bonnet edge;
— the legs and the car bumper.

In general, lower-limb trauma is the most common form of pedestrian injury, while head injury is responsible for most pedestrian fatalities (*62*).

Results from both the Australian and the European New Car Assessment Programmes, using four performance tests, indicate that, in general, the new cars tested did not provide protection for pedestrians and cyclists (*161, 162*).

Users of motorized two-wheelers

Hospital studies in Thailand show that 75–80% of road casualties and 70–90% of road deaths are among motorized two-wheeler users (*15*).

Motorized two-wheeler users tend to sustain multiple injuries, including to the head, chest and legs. The majority of the fatal injuries are to the head. Lower-leg injuries – either from direct contact with the impacting vehicle or as a result of being crushed – contribute substantially to morbidity (*163*). A Malaysian study found that leg injuries usually required a longer period of inpatient stay than other non-fatal injuries (*164*).

Considerable research has been conducted in Europe to identify effective leg protection for motorized two-wheeler riders and to develop suitable air bags to protect riders in case of a frontal impact (*165*).

Bus and truck occupants

Buses with passengers, minibuses and trucks are frequently involved in crashes in low-income countries. The use of open-backed vehicles for transporting passengers in rural areas is widespread and risks ejecting passengers (*166*). In New Delhi, India, around two thirds of crashes involve buses or trucks (*5*).

In many low-income and middle-income countries, second-hand trucks and buses are imported without the crash-protective features – such as occupant restraints – that are present in high-income countries. Such vehicles have a poor crashworthiness performance, and also poor stability when fully laden or overloaded, as they frequently are.

The urban centres of low-income and middle-income countries typically contain a great mix of vehicles. Incompatibility of size between different classes of road vehicles is a major risk factor, especially in impacts between cars and large trucks. The power of the larger vehicle – its mass, geometry and structural properties – increases rates of injury and death many times compared with an equivalent car-to-car crash (*71, 167*).

Safer bus and truck fronts have been identified as an urgent need (*71, 141, 168*). A study in New Delhi showed that of 359 crashes involving trucks, 55% also involved vulnerable road users. Impacts between the fronts of trucks and pedestrians resulted in severe leg injuries at 25 km/h. At 35 km/h the head sustained severe injuries, as did the chest at 45 km/h. Contact with bumpers resulted in pelvic injury (*141*).

Non-use of crash helmets by two-wheeled vehicle users

Users of motorized two-wheelers

The main risk factor for motorized two-wheeler users is the non-use of crash helmets. Use of helmets has been shown to reduce fatal and serious head injuries by between 20% and 45% and to be the most successful approach for preventing injury among motorized two-wheeler riders (*169*).

Head trauma is the main cause of death and morbidity in motorized two-wheeler users, contributing to around 75% of motorized two-wheeler deaths in European countries (*170*). Fatal head injury resulting from crashes is estimated to account for 55–88% of motorized two-wheeler rider deaths in Malaysia (*171*). Substantial growths in motorized two-wheeler use in low-income and middle-income countries are being accompanied by an increase in head injuries.

Kulanthayan et al. (*172*) found that non-helmeted motorized two-wheeler users were three times more likely to sustain head injuries in a crash than those wearing helmets. A study of crash victims admitted to a neurosurgery ward in New Delhi, India showed that riders who used any type of helmet with some protective padding benefited (*94*). Helmet use varies from slightly over zero in some low-income countries to almost 100% in places where laws on helmet use are effectively enforced. Helmets constructed in some low-income and middle-income countries are not always appropriately designed. In some countries, such as Malaysia, special exemptions from wearing a helmet are given to certain religious groups, such as Sikhs. In several low-income countries, helmet use has been found to be lower at night (*173, 174*). Though the wearing of helmets has generally been widespread in most high-income countries, there is some evidence of a decline. In the United States, for example, helmet use fell sharply to 58% in 2002 from 71% recorded two years previously (*175*).

Studies in low-income countries have found that more than half of adult motorized two-wheeler riders do not wear their helmets properly secured (*172, 176*). Child passengers rarely wear helmets and if helmets are used at all they are likely to be adult helmets, providing almost no protection (*177*). A study in California, United States, found that nearly half of motorcyclists used non-standard helmets and that these riders incurred more frequent head injuries than those who wore either standard helmets or no helmets at all (*178*).

Bicycle helmets

Admissions to hospital and deaths from bicycle-related trauma are usually due to head injury (*179*). Bicycle helmets reduce the risk of head and brain injuries by between 63% and 88% (*180–182*).

A meta-analysis of studies on the benefits of bicycle helmets found that wearing a helmet had an odds-ratio efficacy of 0.40, 0.42, 0.53 and 0.27 for head, brain, facial and fatal injuries, respectively (*183*).

Several countries have introduced legislation on bicycle helmet wearing, including Australia, New Zealand, Sweden and the United States. In countries which do not require the use of helmets by law, the wearing rate is normally less than 10%

(*184*). Rates of helmet use tend to be higher among younger children, as opposed to teenagers and adults.

Non-use of seat-belts and child restraints in motor vehicles

Failure to use seat-belts is a major risk factor for vehicle occupants. The most frequent and most serious injuries occurring in frontal impacts to occupants unrestrained by seat-belts are to the head (*185*). The effectiveness of seat-belts depends upon the type and severity of the crash and the seating position of the occupant. The benefits of seat-belts in terms of injury reduction and their effectiveness in different types of impacts are set out in Tables 3.7 and 3.8.

Crash research in various countries has found that rates of seat-belt wearing are substantially lower in fatal collisions than the general average rate. For example, while the overall proportion of occupants wearing seat-belts in traffic is around 90%, only around 55% of drivers in fatal crashes in Finland wore seat-belts (*189*), and about 35% in Sweden (*190*).

While seat-belts may cause injuries, these are, typically, minor abrasions and bruising to the chest and abdomen, and without the seat-belts the injuries would have been far more severe (*191*). The effectiveness of front seat-belts in a frontal collision is reduced by the rear loading caused by unrestrained passengers in the back seat. This phenomenon of rear loading can cause severe chest injuries to the occupants of front seats. It can also occur when there is unrestrained luggage on the rear seats. Earlier concerns that seat-belt use would lead routinely to death by entrapment or to problems in pregnancy, or would encourage drivers to take greater risks, have not been borne out by empirical evidence (*185, 192–194*).

TABLE 3.7

Injury reduction benefits of seat-belts for car drivers and front-seat passengers

Year	Reference	Injury reducing effect (%)		
		Fatal collisions	Moderate and severe injuries	All severities
1976	Griffith et al.	41		
1984	Hobbs & Mills		65	
1986	Department of Transport, USA			40–50
1987	Malliaris & Digges	50 (drivers) 40 (front-seat passengers)		
1987	Evans	41		
1987	Campbell	65 (drivers) 54 (front-seat passengers)	51–52 (drivers) 43–44 (front-seat passengers)	
1996	National Highway Traffic Safety Administration, USA		48	
1996	Cooperative Crash Injury Study, UK (unpublished)		53	
2003	Cummings et al.	61		
	Effectiveness range	40–65	43–65	40–50

Source: reproduced from references *186, 187.*

TABLE 3.8

Injury reduction effects of seat-belts for various types of car crash

Crash type	Proportion of all crashes (%)	Driver seat-belt effectiveness in different crash types (%)
Frontal	59	43
Struck side	14	27
Non-struck side	9	39
Rear	5	49
Roll-over	14	77

Source: reproduced from reference *188,* with the permission of the publisher.

Extent of the problem

Rates of seat-belt use vary greatly among different countries, depending upon the existence of laws mandating their fitting and use, and the degree to which those laws are enforced. In many low-income countries, there is no requirement for belts to be fitted in motor vehicles or to be used. Despite legislation, though, the extent of non-use remains significant in highly-motorized countries, with low rates of front seat-belt wearing in some places and generally low rates of rear seat-belt wearing. In the United States, front seat-belt use was reported in 2002 as 75%, compared with 58% in 1994 (*175*). In European Union countries in the mid-1990s, wearing rates of front seat-belts ranged between 52% and 92%, and those of rear seat-belts between 9% and 80% (*186*).

In the Republic of Korea, rates of seat-belt usage rose sharply among drivers, from 23% in late 2000 to 98% in August 2001, following a national campaign of police enforcement together with publicity and a doubling of the fine for non-use (*195*). In many other places, including some eastern European countries and parts of Central and South America, usage rates are generally much lower. In Argentina, for instance, front seat-belt use is around 26% in the capital Buenos Aires and 58% on national highways (*196*).

A survey in Kenya found that of over 200 road crash survivors only 1% reported seat-belt use, leading the authors of the study to conclude that "the demand for seat-belts has yet to become part of the culture in Kenya" (*59*).

In some countries, usage among drivers tends to be high on motorways but low in urban areas. Young male drivers have been found to use their safety belts less often than other groups and are also more often involved in crashes (*197*).

Child restraints

Methods of restraining children in motor vehicles, and in particular the use of child safety seats, vary within and between countries. In high-income countries, usage rates of child restraints tend to be high – about 90% in Australia and 86% in the United States. In car travel in low-income countries, though, their use is rare.

Child restraints work in the same way as adult seat-belts. Rear-facing seats have been shown to be particularly effective (see Table 3.9). When travelling rearwards, the forces from a sudden deceleration will be distributed over the child's body and head in an optimal way, which markedly increases effectiveness.

TABLE 3.9

Injury reduction benefits of child restraints

Type of restraint	All injuries (%)	Severe injuries (%)
Rearward facing	76	92
Forward facing	34	60

Source: reproduced from reference *186*, with the permission of the publisher.

In terms of preventing fatalities, the use of safety seats for children travelling in cars offers a very high level of protection. It has been shown to reduce infant deaths in cars by approximately 71% and deaths of small children by 54% (*198*). Nevertheless even when restrained, children in cars face a particular risk from side impacts. A study in Sweden showed that approximately 50% of fatally-injured children aged up to 3 years had been involved in side impact collisions (*199*). The European New Car Assessment Programme has also shown that current restraints, when fitted in cars, do not fully constrain the movement of the child's head and prevent contact with the car's interior (*154*).

Air bags

Driver air bags are designed to provide protection for belted and unbelted occupants in frontal crashes. Estimates of their effectiveness in reducing driver deaths in purely frontal crashes range from 22% to 29% (*187, 200–202*).

The potential hazard of combining air bags with rear-facing child safety seats in the front seat was first reported in 1974 by Aldman et al. (*203)*, and more recently by Anund (*204*) and Weber (*205*). In the United States, there have been many cases of fatally injured and severely injured children where the injuries – attributed to air bags that inflated during low-speed car crashes – might not otherwise have been sustained. Given the popularity of rear-facing child safety seats in Europe and the almost universal practice in high-income countries of fitting air bags on the front passenger side of the vehicle, action has recently been taken in some places to legislate for the provision of warning labels in cars and of automatic sensors that can detect the presence of occupants seated in front of the air bag.

Studies have shown that there is a substantial amount of incorrect use of both adult seat-belts and child restraints, which markedly lessens their potential to reduce injury (*206, 207*).

Roadside objects

Impacts between vehicles leaving the road and solid roadside objects such as trees, poles and road signs are a major road safety problem worldwide. According to research in Australia and several European Union countries, roadside hazards contribute to between 18% and 42% of fatal crashes (*208, 209*).

These collisions are usually single-vehicle crashes and frequently involve young drivers, excess or inappropriate speed, the use of alcohol or driver fatigue. Another problem related to impacts with objects off the road is the occurrence of crashes caused by restricted visibility, due to the poor siting of these objects.

The linkages between vehicle crash protection and roadside crash protection need to be strengthened. For example, cars do not provide protection for occupants in head-on collisions at speeds above 60–70 km/h (or even lower limits with other types of impact), although many cars travel at these and higher speeds. For this reason, the road environment needs to be designed so as to eliminate head-on collisions – into trees, poles and other rigid objects – at high speeds, where the car itself cannot offer sufficient protection. Cars, roads and other aspects of the traffic system must be designed in a mutually-linked way (*155*).

Risk factors influencing post-crash injury outcome

Studies worldwide have shown that death was potentially preventable in a large proportion of those who died as a result of road crashes before they reached hospital (*210, 211*).

A review of European studies of mortality in road traffic concluded that about 50% of deaths from road collisions occurred within a few minutes at the scene of the crash, or else on the way to a hospital but before arrival there. For those patients taken to hospital, the data suggest that comparatively few deaths, only about 15%, occur between one and four hours after the incident, while around 35% occur after four hours. The time between the incident and death varies considerably between patients and between countries (*212*).

A comparative study of mortality among seriously injured patients across a range of countries found that for low-income and middle-income countries, the vast majority of deaths occurred in the pre-hospital phase (see Table 3.10). The study also showed clearly that the probability of dying increased as the socioeconomic level of the victim decreased (*213*). Morbidity outcomes are also influenced by factors related to post-impact care. A study in the United Kingdom, for instance, suggested that 12% of patients who had sustained serious skeletal trauma went on to experience significant disability that was preventable (*214*).

TABLE 3.10

Proportion of road deaths by setting in three cities

Setting	Kumasi, Ghana (%)	Monterrey, Mexico (%)	Seattle, USA (%)
Pre-hospital	81	72	59
Emergency room	5	21	18
Hospital ward	14	7	23

Source: reference *213*.

In the case of major injuries, the potential help towards recovery that survivors can receive can be viewed as a chain with several links (*212*):

— actions, or self-help, at the scene of the crash, by the victims themselves, or more frequently by bystanders;
— access to the emergency medical system;
— help provided by rescuers of the emergency services;
— delivery of medical care before arrival at the hospital;
— hospital trauma care;
— rehabilitative psychosocial care.

Pre-hospital factors

Weak public health infrastructure in many low-income and middle-income countries is a major risk factor. In high-income countries, the pre-hospital risk factors are not so pronounced, but where they exist, are associated with the need to improve the existing elements of post-impact care. In most highly-motorized countries, the large volume of traffic and the high incidence of mobile telephones usually lead to the early alerting of the medical services about a crash. However, in low-income countries, most of the population does not have access to even the most basic form of emergency medical service. Evacuation and transport to hospital is more often carried out by bystanders, relatives, commercial vehicles or the police (*215*). An African study found that the police and hospital ambulances evacuated only 5.5% and 2.9%, respectively, of crash victims in Kenya (*216*).

Research in the United States has shown that the transport by ambulance can be a risk, as a result of the high speeds of travel and the frequent lack of available restraint. Compared with police cars and fire trucks, ambulances experience the greatest proportion of fatal crashes in which occupants are killed as well as the greatest proportion of crashes in which occupants are injured (*217*).

In low-income countries, many victims do not possess social security, health cover or life insurance and therefore lack access to hospital care (*59, 60*). In a study carried out in Ghana, overall hospital use was found to be very low, with only 27% of all injured people using hospital services. Among those with severe injuries, only 60% of urban casualties and 38% of rural casualties received hospital care (*210*).

Hospital care factors

Lack of trained expertise in trauma care

Trauma treatment in high-income countries is usually seen as a chain of care performed by well-trained practitioners, even if many of its elements have room for improvement (*212, 213*). In low-income countries, the post-impact chain of care is often delivered by personnel lacking formal training. A study in Mexico showed that this was the case throughout much of the emergency medical services (*218*). In Ghana, a study of 11 rural hospitals that received large numbers of road traffic casualties was staffed exclusively by general practitioners without trauma training (*210*).

A further risk factor in low-income countries is the lack of sufficient numbers of formally trained surgeons. In the late 1980s, it was estimated there were 50 surgeons per 100 000 people in the United States, as opposed to only 7 per 100 000 in Latin America and 0.5 per 100 000 in Africa (*219*).

A study of 2000 trauma admissions in the main hospital in Kumasi, Ghana, found a mean 12-hour delay before the start of emergency surgery as well as low rates of usage of key equipment, despite its availability (*210*).

Lack of equipment

Adequate trauma care requires a range of medical specialities and equipment, as well as appropriate logistic support to ensure that the equipment and other specialities are available to the patient on arrival. In reality, delays are substantial and frequent, introducing avoidable risks of complications.

In the study of 11 Ghanaian hospitals, essential low-cost and reusable equipment was lacking – because of poor organization rather than the cost. For example, no hospital had chest tubes and only four had equipment to ensure a patent airway (*210*). In Kenya, in a survey of hospital administrators, only 40% of the health facilities – both outpatient and inpatient services – were reported to be well prepared and have key supplies available (*216*).

Conclusion

Analysis of available crash data and other road traffic research show that while the main road safety problems experienced in various parts of the world often differ in quality and quantity, they have many characteristics in common. The dominant, common characteristics of the risks associated with road traffic are as follows:

- Unnecessary travel, the choice of less safe travel modes and routes, and unsafe mixes of traffic all lead to increased risk.

- The design of roads and road networks is an important factor. Exposure to risk is increased significantly by road networks failing to route heavy traffic around populated areas or to separate pedestrians from motorized traffic.
- Excess and inappropriate speed is widespread and may contribute to around 30% of road traffic crashes and deaths. In collisions at 80 km/h, car occupants run a 20 times higher risk of being killed than at 30 km/h. Pedestrians have a 90% chance of surviving car crashes at 30 km/h or below, but less than a 50% chance of surviving impacts at 45 km/h or above.
- Impairment by alcohol continues to contribute to crash injury and increases the risk. All non-zero BAC levels carry more risk than zero BAC, and crash risk starts to rise sharply at levels of 0.04 g/dl. Legal BAC limits set at 0.10 g/dl allow three times more risk than limits set at 0.05 g/dl; at 0.08 g/dl, the risk is twice as much as that at 0.05 g/dl.
- Young novice drivers are at increased risk of crash injury; the risk among teenage drivers is higher than among any other comparable age group. Excess or inappropriate speed is a common contributory factor in crashes involving young drivers.
- Pedestrians, cyclists and motorized two-wheeler users bear a disproportionate share of the global road injury burden and are all at high risk of crash injury.
- For all road users, the risk of crash injury is increased by failing to see and failing to be seen. If daytime running lights were fitted and used, almost a third of all motorized two-wheeler crashes involving lack of visibility could be avoided; in the case of cars, more than 10% of such crashes could be avoided.
- The non-use of seat-belts and child restraints more than doubles the risk of serious and fatal injury, as does the non-use of bicycle helmets. Similarly, the non-use of crash helmets by motorized two-wheeler users almost doubles their risk of serious or fatal head injury.
- Crash analysis shows that the majority of pedestrian fatalities involve impact with unprotective car fronts. If all cars were designed to provide protection equivalent to that of the best car in the same class, an estimated half of all fatal and disabling injuries to car occupants would be avoided. Roadside design and the positioning of roadside objects play key roles in determining crash injury, as well as influencing the behaviour of road users.
- Inadequate post-crash care is a major problem in many places. The availability and quality of such care has a substantial effect on whether a road traffic injury leads to subsequent death or disability.

The availability in low-income countries of data on road traffic crashes is often basic. For a proper understanding of the risk factors predominating in local settings, more investment for systematic, independent and high-quality research is needed, particularly from high-income countries. Such worldwide research into the causes of crashes and crash injury is essential for achieving safer traffic systems.

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