Pedestrians & Cyclists

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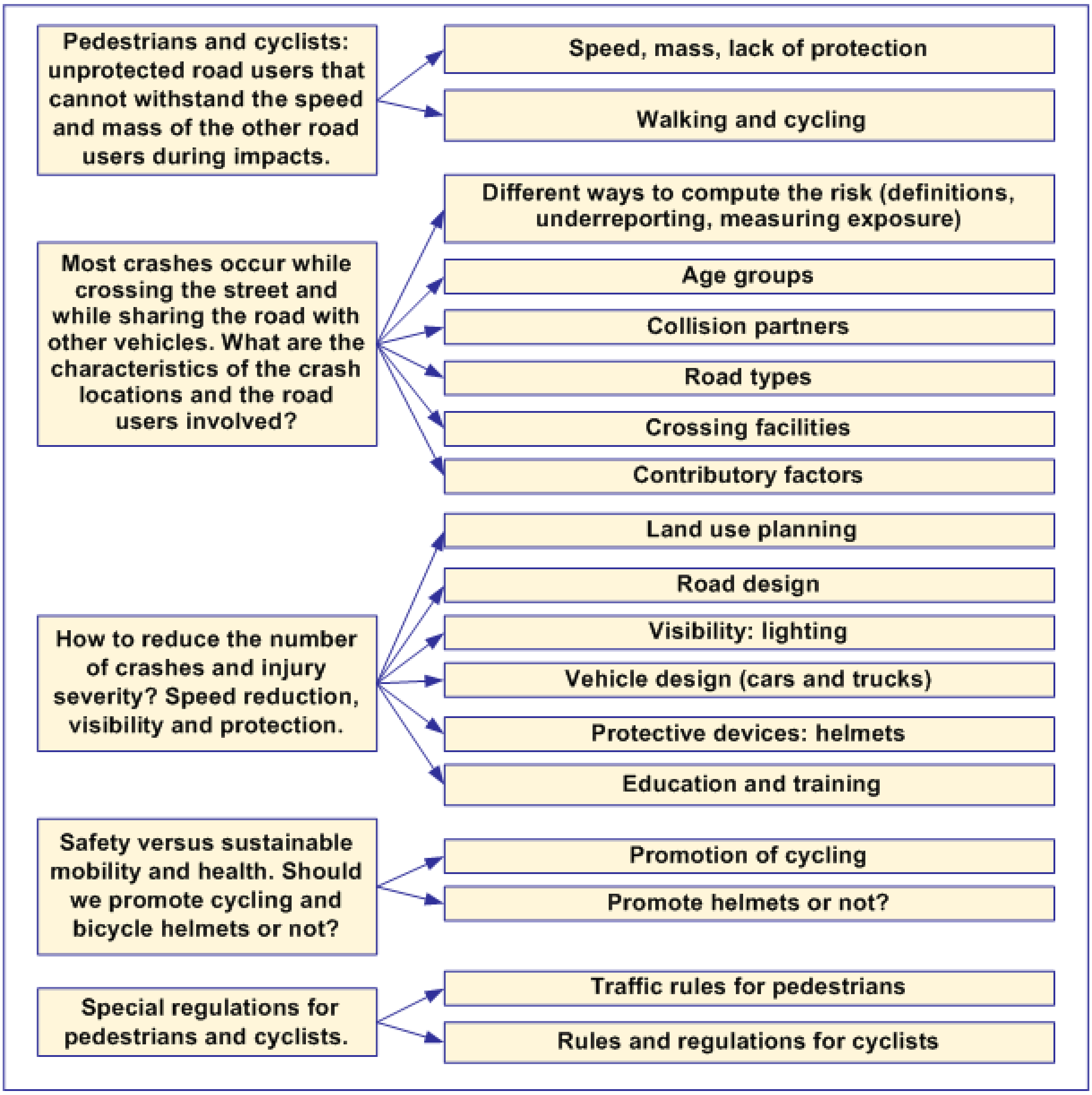
Pedestrians and Cyclists

This text on pedestrians and cyclists safety, reviews the scientific studies on the magnitude and nature of the safety problem, the contributing accident factors, and the effectiveness of countermeasures.

For information on the development of casualty frequencies and accident circumstances over the period 1995-2004 per European country, please consult the Basic Fact Sheet Pedestrians and the Basic Fact Sheet Bicycles on the Data section of the website.

Diagram & Summary



Unprotected road users

Walking and cycling are transport modes where relatively unprotected road users interact with traffic of high speed and mass. This makes pedestrians and cyclists vulnerable. They suffer the most severe consequences in collisions with other road users because they cannot protect themselves against the speed and mass of the other party.
Of all journeys, 20-40% are travelled by cycle or on foot, with the highest percentage in the Netherlands and the lowest in Finland. Trips on foot take place most frequently in Great Britain, whereas bicycle trips are most frequent in the Netherlands, Denmark, and Sweden. Some groups of traffic participants walk or cycle more than others. These differences are also reflected in their crash involvement. Walking is particularly important for children below the age of 12 and adults aged 75 and above. The bicycle is used most frequently by adolescents (12-17 years of age).

Crash characteristics

Of all traffic fatalities in EU countries, the proportion of pedestrian fatalities is about 17% and the proportion of cyclist fatalities is about 6%. Age groups that have the highest percentage of *pedestrian* fatalities are children younger than 10 years of age and adults aged 65 years or older. Cyclist fatalities have the highest share among children between 6 and 14 years of age. The percentages for these age groups are about twice as high as the average percentages for all age groups.
Most fatalities, severe and slight injuries to pedestrians and cyclists occur in urban areas. Motor vehicles (cars, lorries, and buses) account for over 80% of vehicles striking pedestrians and cyclists. Crashes involving pedestrians and cyclists occur frequently at facilities designed for pedestrians and cyclists such as pedestrian crossings, cycle tracks, and cycle lanes. This means that these facilities are not necessarily good enough to prevent crashes. However, pedestrian crossings might also be the location at which roads are most often crossed.
Factors that have been identified as contributory factors in the causation of pedestrian and cyclist crashes and injuries are the speed of motorised vehicles, the weight and design of motor vehicles, the lack of protection of pedestrians and cyclists, their visibility and vehicle control, and alcohol consumption.

How to reduce the number of crashes and decrease injury severity

Measures that can be taken to reduce the future number of crashes involving pedestrians and cyclists, and/or to decrease the severity of resulting injuries, relate to:

- The traffic system itself, such as separation of motorised traffic from non-motorised traffic, area-wide speed reduction, and the provision of walking and cycling networks
- Proper design of pedestrian and cyclist facilities
- Improvement of the visibility of pedestrians and cyclists
- Vehicle design, in particular crash-friendly car fronts and side-underrun protection on lorries
- The use of protective devices like bicycle helmets, and
- Education and training of pedestrians and cyclists as well as drivers.

Special regulations for pedestrians and cyclists

Pedestrians and cyclists are both subject to the traffic rules defined in the Vienna Convention of 1968. In some countries, additional regulations have been defined. These relate to supplementary regulations regarding mandatory equipment to ensure cyclists' visibility (e.g., pedal reflectors, spoke reflectors), standards for children's bicycle seats (e.g., seat attachment, footrests), minimum age for cycling on public roads, and helmet legislation.

1. Pedestrians and cyclists: unprotected road users

Walking and cycling are transport modes where relatively unprotected road users interact with traffic of high speed and mass. This makes pedestrians and cyclists vulnerable. They suffer the most severe consequences in collisions with other road users because they cannot protect themselves against the speed and mass of the other party. Preventing collisions between fast and slow traffic is, therefore, one of the most important requirements for safe road use by pedestrians and cyclists. Other measures have to be sought in making the crash opponents less harmful to pedestrians and cyclists (see Vehicle design).

Of all journeys, 20-40% are travelled by cycle or on foot, with the highest percentage in the Netherlands and the lowest in Finland. Trips on foot take place most frequently in Great Britain, whereas bicycle trips are most frequent in the Netherlands, Denmark and Sweden [34]. Some groups of traffic participants walk or cycle more than others. These differences are also reflected in their crash involvement. Walking is particularly important for children below the age of 12 and adults aged 75 and above. The bicycle is used most frequently by adolescents (12-17 years of age) [34].

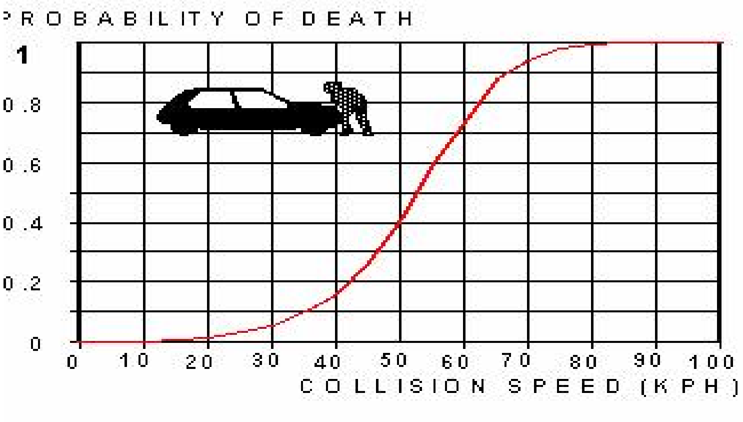
1.1 No speed, no mass, and no protection

Speed is a fundamental risk factor in traffic. Firstly, speed is related to crash rate [1]. From several studies of the relationship between speed and crash rate, we can conclude that higher absolute speeds of individual vehicles are related to an exponential increase in crash rate [31] [32]. Secondly, speed is related to crash and injury severity. When the collision speed increases, the amount of energy that is released increases as well. Part of the energy will be 'absorbed' by the human body. However, the human body tolerates only a limited amount of external forces. When the amount of external forces exceeds the physical threshold, severe or fatal injury will occur. Hence, higher speeds result in more severe injury (see Speed and injury severity). This is particularly true for occupants of light vehicles, when colliding with more heavy vehicles, and for unprotected road users, such as pedestrians and cyclists when colliding with motorised vehicles.

Weight (mass) also plays a very prominent role in the outcome of crashes. When a heavy and a light vehicle collide, the occupants of light vehicles are far more at risk of sustaining severe injury [7]. This is because the energy that is released in the collision is mainly absorbed by the lighter vehicle. Pedestrians, cyclists and moped riders have the largest risk of severe injury when colliding with a motor vehicle. The difference in mass is huge and the collision energy is mainly absorbed by the lighter 'object'. In addition, pedestrians and cyclists are *completely unprotected*: no iron framework, no seatbelts, and no airbags to absorb part of the energy. For a collision between a car and a pedestrian, the following relationship between speed and survival chance was established by Ashton and Mackay (1979; cited in ETSC [19]):

Car speed	% fatally injured pedestrians
32 km/h	5%
48 km/h	45%
64 km/h	85%

In a graph, the probability of fatal injury for a pedestrian colliding with a vehicle looks like this (source: Pasanen [37])



1.2 Walking and cycling as transport modes

Of all journeys, 20-40% are travelled by cycle or on foot, with the highest percentage in the Netherlands and the lowest in Finland. Trips on foot take place most frequently in Great Britain, whereas bicycle trips are most frequent in the Netherlands, Denmark and Sweden [34].

Some groups of traffic participants walk or cycle more than others. These differences are also reflected in their crash involvement (see Crash characteristics). Age groups for which walking is particularly important, are children below the age of 12 and adults aged 75 and above. The bicycle is used most frequently by those younger than 18 years of age [34].

- Walking as a transport mode
- Cycling as a transport mode
- Age groups most involved in walking and cycling

1.2.1 Walking as a transport mode

Walking as a means of transport is commonly used for rather short trips. This means that it is actually difficult to assess pedestrian mobility at country level, as the national travel surveys often do not register the shorter trips. Also, the walking parts of trips made primarily by public transport are usually not taken into account. At present, the importance of walking is therefore underestimated [60].

Survey data from a selection of seven European countries show that 12-30% of all trips is made by walking (as main transport mode), the highest figure being for Great Britain [34]. For short trips under 5 km, the share of walking is higher, with a maximum of 45% in Great Britain. The average length of walking trips varies from just under 1 km (Great Britain) to 2.8 km (Finland). It should be noted, however, that the extent of coverage of short trips may vary from country to country in the national travel surveys. This will affect the comparability of average trip length and the share of walking. In Great Britain, all trip lengths are included, whereas in Denmark trips shorter than 300 metres are excluded from the survey and all trips between 300 and 1500 metres are recorded to be 1 km [34].

Walking is a way of travelling used mainly for two purposes: short trips to specific destinations such as shops when there is probably not too much to carry, and leisure trips where the walking in itself is the main purpose [28]. About 15-30% of all person kilometres walked (on an average day) is for shopping purposes. Home-leisure trips cover about 30-55% of the person kilometres, with Switzerland at the top and Finland at the bottom [34].

1.2.2 Cycling as a transport mode

In most countries, a high proportion of people own a bicycle (in Norway, for instance, 70% of adults own a bicycle, in Switzerland, 69% of households own a bicycle). The number of bicycles per 1 000 inhabitants ranges from 52 in the Czech Republic to 1 000 in the Netherlands. What differs considerably from one country to another is the way in which the bicycle is used. Some cyclists use it every day, as a means of transport, while others do so only occasionally [16].

Survey data from a selection of seven European countries show that 3-28% of all trips made by cycling, the highest figure being for the Netherlands [34]. For short trips under 5 km, the share of cycling varies from 12% (Finland) to 39% (the Netherlands). The average trip length for cycling is around 3 km in most European countries.

The bicycle is used for short trips to shops and for leisure purposes where the bicycle-tour probably is an aim in itself. However, cycling is also a common way for travelling to work [28]. Between about 30 and 40% of the person kilometres by bicycle is travelled on home-work trips. Home-leisure trips cover about 20-45% of the person kilometres, with the most made in Switzerland and the least in Finland [34].

1.2.3 Age groups most involved in walking and cycling

Some groups of traffic participants walk or cycle more than others. These differences are also reflected in their crash involvement. Age groups for which walking is particularly important, are children below the age of 12 and adults aged 75 and above. Data from the Netherlands illustrate this. People aged over 75 years make one-third of their trips on foot. They use the car slightly more often (38%), but considerably less often than younger adults aged 25 to 74 years, who use this vehicle for more than half of their trips. The bicycle is considerably less popular for elderly people: they use the bicycle for only 17% of all trips. Together with people aged between 25 and 29, they use the bicycle the least.

The bicycle is more important in the youngest age categories. Data from the Netherlands (Table 1) show that children in the age group from 0 to 11 years travel by bicycle as often as they walk (both 29%). The same is the case for young adults aged between 18 and 24 years. Next to walking (20%) and cycling (23%), public transport (18%) is a commonly used mode of transport among them. For young people in secondary school (12 to 17 years of age), the bicycle is by far the most important vehicle: they use their bicycle for no less than 52% of all trips.

Data from other European countries show the same pattern: young children and older adults walk the most, whereas somewhat older children cycle the most [34] [28].

	0-11	12-17	18-24	25-29	30-39	40-49	50-59	60-74	75+
Pedestrian	29%	18%	20%	19%	18%	17%	18%	25%	34%
Bicycle	29%	52%	23%	17%	20%	23%	22%	24%	17%
Moped/mofa	0%	3%	2%	1%	1%	1%	1%	0%	1%
Motorcycle/scooter	0%	0%	0%	0%	0%	0%	0%	0%	0%
Passenger car	40%	17%	37%	56%	56%	55%	54%	46%	38%
Bus	1%	5%	8%	2%	1%	1%	2%	2%	4%
Tram/metro	0%	1%	3%	2%	1%	1%	1%	1%	1%
Train	0%	2%	6%	3%	2%	2%	1%	1%	1%
Other	1%	1%	0%	0%	0%	0%	0%	1%	3%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 1 Modal split by age group in the Netherlands. Source: Wegman & Aarts 2005

2. Crash characteristics: where and how?

The trends for the number of fatalities among pedestrians and cyclists in Europe show that since 1980 both numbers have decreased by about 65 and 55% respectively. However, of all traffic fatalities, the proportion of pedestrian fatalities is still about 17%, and the proportion of cyclist fatalities is about 6%. Age groups that have the highest percentage of pedestrian fatalities are children younger than 10 years of age and adults aged 65 years or older. Cyclist fatalities have the highest share among children between 6 and 14 years of age. The percentages for these age groups are about twice as high as the average percentages for all age groups. The following sections contain information about the circumstances in which pedestrian and cyclist crashes take place. However, the chapter starts with some data considerations: what crashes are considered to be traffic-related, and how well are they reported in the police crash statistics.

- Data considerations
- General trends in number of fatalities
- Share of pedestrian and cyclist fatalities
- Age groups most involved in fatal crashes
- Collision partners
- Road types
- Crossing facilities
- Contributory factors

2.1 Data considerations

Which crashes and injuries are traffic-related and how well are they reported in police crash statistics

2.1.1 Definition of a traffic-related crash

Not all crashes involving pedestrians and/or cyclists are considered to be traffic-related. According to the UNECE definition, road traffic accidents are those accidents:

a) Which occurred or originated on a way or street open to public traffic
b) Which resulted in one or more persons being killed or injured and
c) In which at least one moving vehicle was involved.
These accidents therefore include collisions between vehicles, between vehicles and pedestrians, and between vehicles and animals or fixed obstacles. Single vehicle accidents, in which one vehicle alone (and no other road user) was involved, are included. Multi-vehicle collisions are counted as only one accident provided that the successive collisions happen at very short intervals. United Nations Economic Commission for Europe, 2005

As a result, an accident in which a pedestrian fell as a result of loose paving stones is not regarded as a traffic accident. The same applies for an accident in which a pedestrian fell while boarding or alighting from a bus.

2.1.2 Certain types of crashes are underreported

Pedestrian and cyclist crashes are heavily and disproportionally underreported in the police crash statistics compared to what hospital records and other studies show [34] [20]. Data from Great Britain and the Netherlands clearly show that the amount of under-representation becomes larger as the victim's transport mode changes from passenger car to cyclist (Table 2.) The table below also shows that the level of under-representation increases as injury severity decreases. For all severities, casualties among cyclists are far less reported in comparison with casualties among other road users. Cycle accidents in which no other vehicle was involved are heavily under-reported. Examples of such accidents are accidents in which the cyclist fell, slipped, or collided with an obstacle.

	Great Britain			The Netherlands		
	Fatal	Severe	Slight	Fatal	Hospitalised	Slight
Passenger car	100%	89%	77%	96%	92%	33%
Motorcycle/scooter	100%	70%	51%	94%	63%	13%
Bicycle	100%	33%	21%	86%	31%	4%
Pedestrian	100%	85%	67%	90%	56%	20%
Total	100%	76%	62%	93%	60%	13%

Table 2 Percentages of casualties reported. Source: OECD, 1998, SWOV-AVV

2.1.3 Risk and measurement of exposure

Comparing the number of crashes among cyclists and pedestrians with those among car drivers and/or passengers, introduces a number of problems. First of all, as car trips are dominant, and the trip length of car drivers is much longer than that of non-motorised road users such as pedestrians or cyclists, it is logical that the largest percentage of all crashes is that of car drivers and/or passengers. Therefore, the amount of exposure should be included in the comparison of crash numbers. Usually exposure is measured by the number of trips or the number of kilometres travelled. Another, maybe more representative exposure measure would be hours spent in traffic. A calculation performed in the United Kingdom, using data from 1988, shows how differences in casualty rates vary with the unit of exposure chosen:

	Fatalities	Fatality rate per 100 million.		
		Trips	kilometres	hours
Passenger car	2142	5.2	0.4	12.4
Motorcycle/scooter	670	122	11.4	342
Bicycle	227	12.5	4.6	64
Pedestrian	1753	7	6.6	27

Table 3 Number of casualties per units travelled by different types of road users in 1988. Source: PROMISING [40]

This table shows that, based on the fatality rate in terms of distance (km), walking is about 16 times more dangerous than car travel. However, in terms of time spent travelling, the risks are more similar, with walking being two times more dangerous than being in a car. In terms of number of trips, the risk of walking and driving a car is about the same [60]

A second problem that is introduced when comparing crashes among cyclists and pedestrians with those among car drivers and/or passengers relates to the roads they use. More than one third of all car kilometres are driven on highways that have been made very safe. If only those roads are considered which are also used by cyclists and pedestrians, the crash rate for car driving will be higher [60].

Thirdly, less easily quantifiable measures such as the level of congestion of the roads or behavioural factors such as whether children are accompanied on their journeys also affect exposure to risk. The same applies for cycling experience. The more experienced a cyclist is, the lower his fatality rate is, and vice versa. Not only individual kilometrage matters. Crash rates are also related to the total of amount of cycling in a country. In countries where people cycle a lot, cyclists in general have a lower fatality rate. A similar inverse relationship exists for the number of pedestrians or cyclists crossing at intersections. Summersgill et al.[46] have shown that for pedestrians crossing at intersections, increasing pedestrian flows result in lower crash rates per crossing pedestrian[60][40].
Keeping in mind the limitations that are attached to the use of crash and fatality rates, the figure below gives an indication of the fatality rates for different age groups while walking, cycling, riding a motorcycle, and driving a passenger car:

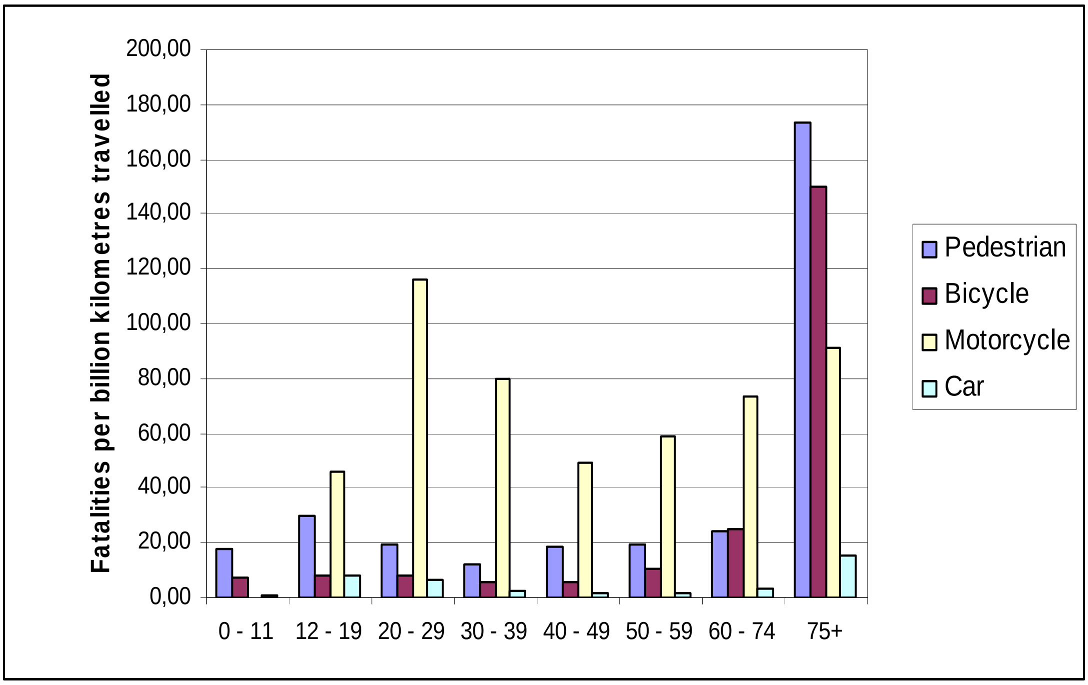


Figure 1 Fatalities per billion kilometres travelled in the Netherlands; 2001-2005. Source: Dutch Ministry of Transport/Statistics Netherlands

2.2 General trends in number of fatalities

The trends for the number of fatalities among pedestrians and cyclists in Europe show that since 1980 both numbers have decreased by about 65 and 55% respectively. To put these figures into perspective: the number of fatalities among car drivers and their passengers only decreased by 35%. It should be noted, however, that reductions in the number of fatalities in a country cannot be evaluated without also looking at trends in mobility. Numbers of pedestrian and cyclist fatalities are affected both by the number of walkers and cyclists and the number of motorised vehicles with which they are likely to be in conflict. But mobility data on pedestrian kilometres and cyclist kilometres are only available for a few countries (see Table 4 for data for the Netherlands and the United Kingdom). Figure 2 shows index figures (1980=100) indicating the extent to which the mean number of fatalities in 16 European countries decreased and the extent to which the mean number of car kilometres travelled in 9 of those countries increased since 1980.

		1981-1983*	1991-1993	2001-2003
Pedestrians	UK	27.5	26	21.3
	Netherlands	10.7	11.7	13.3
Cyclists	UK	5.0	4.8	4.4
	Netherlands	2.7	2.9	3.3

* For the Netherlands, 1985-1987 data are used

Table 4 Billion person kilometres travelled as pedestrian or cyclist. Source: SUNflower +6

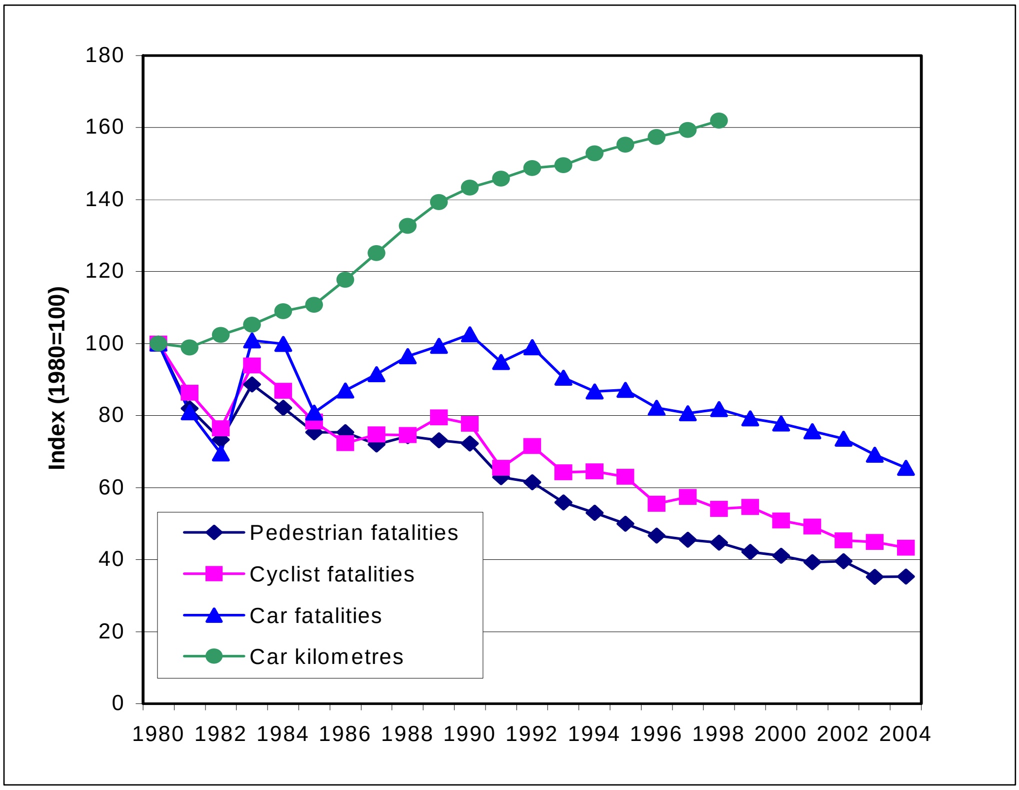


Figure 2 Index numbers of average number of pedestrian, cyclist and car fatalities in 16 European Countries and index numbers for average number of car kilometres in 9 of those countries. Source: IRTAD

Looking at the reductions since 1980 for each country separately, it turns out that the reductions in the number of pedestrian fatalities varied between 35 and 75%, the smallest reduction having taken place in Greece and the largest in Germany, France, the Netherlands, and Austria. National trends in the number of cyclist fatalities were much more unstable. Some trends even showed a temporary increase in the number of fatalities among cyclists (Austria, Denmark, Hungary, Ireland, Norway, and Spain). Nevertheless, in most countries the number of cyclist fatalities eventually decreased gradually. Reductions varied between 15 and 75%, the smallest reduction having taken place in Hungary and Spain and the largest in France, Ireland, and the Netherlands.

Since exposure data are available for only a few countries, the question remains whether the reduction in fatalities were caused by a reduction in kilometrage (exposure to danger) or by an increase in safety per walking kilometre. Using the exposure data from Table 4, Figure 3 shows that in 2003 compared to the 1980s, the numbers of pedestrian fatalities per kilometre travelled and cyclist fatalities per kilometre travelled were reduced to about 50%.

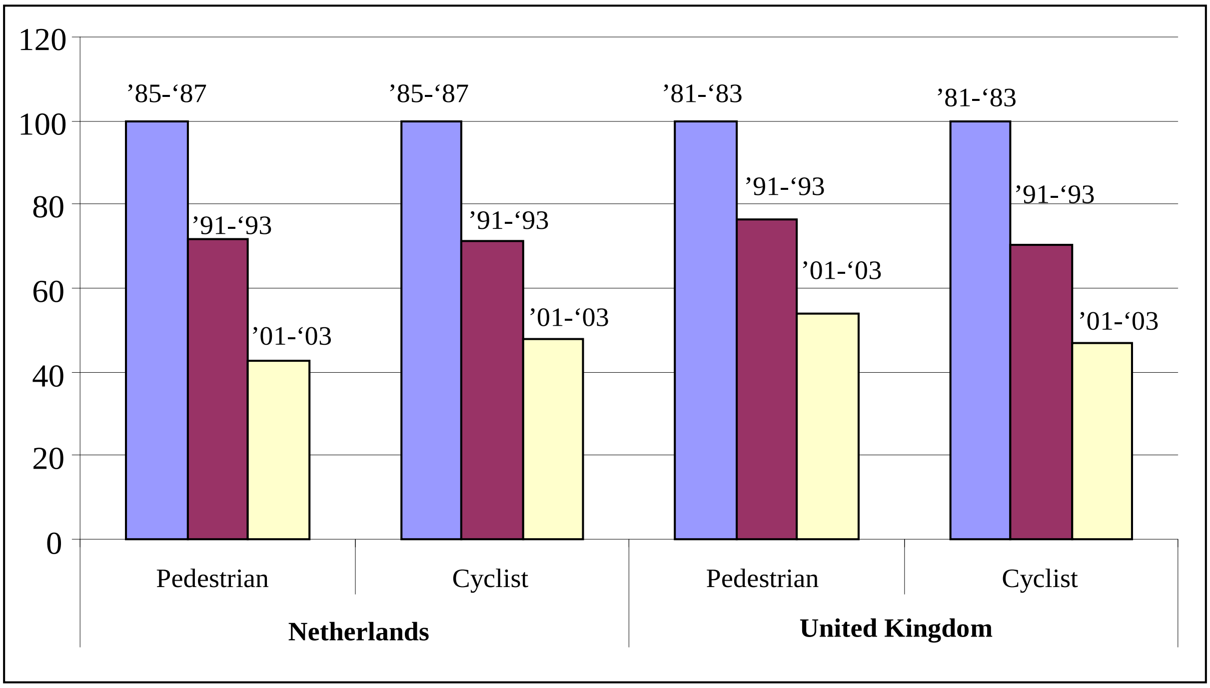


Figure 3 Index of pedestrian fatalaties and cyclist fatalaties per kilometre walked and cycled respectively for the Netherlands and United Kingdom. Source: SUNflower +6

2.3 Share of pedestrian and cyclist fatalities

Of all traffic fatalities, the proportion of pedestrian fatalities is about 17%, and the proportion of cyclist fatalities is about 6% (IRTAD data for 2000-2002). However, differences between countries are large. In countries like the Netherlands and Denmark, where the bicycle is an important daily means of transport, the proportion of cyclist fatalities is much higher (18% and 13% respectively), whereas in Greece and Spain, the proportion of cyclist fatalities is only 1 or 2%. The proportion of pedestrian fatalities varies from 10% in Belgium and the Netherlands to 35% in Poland (more data can be found in Traffic Safety Basic Facts 2005: Pedestrians).

2.4 Age groups most involved in fatal crashes

Age groups that have the highest percentage of *pedestrian* fatalities are children younger than 10 years of age and adults aged 65 and above. About 35 to 40% of the fatalities in these age groups were pedestrian fatalities; twice as much as the average percentage for all age groups (see Share of pedestrian and cyclist fatalities and casualties). The youngest age groups, those younger than 10 years of age, also have the highest percentage of pedestrian casualties: 30-40% of the casualties in these age groups were pedestrian casualties. Cyclist fatalities have the highest share among children between 6 and 14 years of age. About 14% of the fatalities in this age group were cyclist fatalities; twice as much as the average percentage for all age groups. Children between 10 and 14 years of age also have the highest percentage of cyclist casualties: 30% of the casualties in this age group were cyclist casualties.

- Young pedestrians and cyclists
- Elderly pedestrians and cyclists

2.4.1 Young pedestrians and cyclists

Most crashes involving children occur in the late afternoon, when they are either walking back home or playing outside. Several British studies have shown that most of the pedestrian fatalities were running or not paying attention at the time of the crash [45] [8] [52] In the Netherlands, fatal crashes with children are nearly always with a motor vehicle as crash opponent. More than average crash opponents are: cars for young pedestrians, and heavy vehicles (vans and lorries) for young cyclists. Collisions between cyclists and heavy goods vehicles include the well-known crash scenario where the cyclist is in the blind spot of a lorry turning right (or turning left in left-hand side driving countries).

A study of children's exposure to risk as pedestrians and their rate of involvement in crashes in three European countries [6] found a higher fatality rate among children in Great Britain than among children in France and the Netherlands, although children in Great-Britain spent marginally less time in traffic situations as pedestrians and crossed the road less frequently than children in the other two countries. This study found that these exposure rates alone do not explain the increased fatality rate. It was determined that children in Great Britain spend more time on main roads and busy streets than children in the other two countries, that they cross roads between rather than at intersections, and that they are more likely to be accompanied by other children than by adults. These specific examples of exposure are, in turn, connected with the country's residential and traffic infrastructure and, not least, with typical national habits such as adults accompanying children to school [35].

While all children are vulnerable, some children are more at risk than others. There is some evidence of a gender correlation between road safety behaviour and crash involvement. In the United Kingdom, crash patterns for pedestrians reveal a consistently higher rate of incidence for boys than for girls under age 12. In the 5-11 age group, twice as many boys are likely to be killed or severely injured than girls. In the Netherlands, 64% of the traffic victims under 14 are boys. Teenage male bicyclist fatalities exhibit a similar pattern. Teenage female pedestrians may be at particularly high risk once their exposure is taken into account [56] [35].

2.4.2 Elderly pedestrians and cyclists

An important cause of the high fatality rate of older cyclists and pedestrians is the physical vulnerability of elderly people. Since their bones are more brittle and their soft tissue less elastic, they are at higher risk of severe injury, even if the crash forces are the same. At the same time, the elderly have a higher chance of being involved in a crash because locomotive functions deteriorate with increasing years. This deterioration generally consists of slower movement; a decrease of muscular tone, a decrease in fine coordination, and a particularly strong decrease in the ability to adapt to sudden changes in posture (keeping balance). This latter aspect is particularly important for cyclists and pedestrians, but also for public transport users.

Older pedestrians are over-represented in crashes at intersections, particularly those without traffic signals, and being struck by a turning vehicle. Older pedestrians are also over-represented in crashes when they are crossing mid-block sections of roads, particularly on wide multi-lane roads, in busy bi-directional traffic [36]. Pedestrian accidents in which no moving vehicle is involved also occur more frequently among older pedestrians. However, these accidents are not included in the UNECE definition of road accident and are, therefore, heavily under-reported or not included in accident databases at all (see Definition of a traffic-related crash). These include falls when boarding or exiting public transport, falls on footpaths, when stepping off kerbs, and while crossing the road (without being struck by a vehicle). Although injuries resulting from pedestrian falls and other non-collision events are generally not as severe as those where a vehicle is involved, they nevertheless represent a significant cause of trauma for older pedestrians [36].

According to Dutch studies [24], older cyclists are more often involved in crashes with passenger cars than other cyclists. In many of these cases, the cyclist had to cross a multi-lane road. Such incidents (63% of all crashes) occurred particularly inside urban areas (50%), at intersections (19%), and at T-junctions (15%). The latter crashes most often occurred at intersections and T-junctions which were controlled by traffic signs (25%). The difficulties experienced by older cyclists related primarily to manoeuvres such as crossing or turning against the traffic at the intersection. In the majority of these cases, the passenger car was driving on a main road while the cyclist approached from a side road. This crash type resembles the crash type that is over-represented among older car drivers: while turning, the older driver collides with oncoming traffic with right of way on the main road (see Older drivers). Negotiating an intersection clearly represents a “testing of the limits” type of task; it requires a host of age-sensitive functions while simultaneously limiting the usefulness of normal safe driving strategies such as anticipating upcoming events.

2.5 Collision partners

Motor vehicles (cars, lorries, and buses) account for over 80% of vehicles striking pedestrians and cyclists [20] [33]. However, large numbers of cyclist crashes not involving any other vehicle go unrecorded in the crash statistics; in a Dutch study that did include them, over 40% of all cyclist crashes were falls [43]. Crashes with lorries are more common among cyclists than among pedestrians. In the Netherlands, almost one third of the severely injured cyclist casualties in collision with a lorry, occur in the well-known crash scenario where the cyclist is in the blind spot of a lorry turning right.

2.6 Road types

Most fatalities, severe and slight injuries to pedestrians and cyclists occur in urban areas. However, in rural areas, the percentage of fatalities is larger than the percentage of slight injuries [34]. This means that crash severity is higher in rural areas. One explanation might be the higher vehicle speeds in such areas, but other concomitant factors must not be forgotten: the absence of infrastructures reserved for pedestrians, a more acute visibility problem, the increased negative effects of drink driving, et cetera [16]. Although this general tendency is observed (i.e., most casualties occurring in urban areas), in France and Spain there are more fatalities of cyclists in rural areas than in urban areas. In addition, in Spain more pedestrian fatalities occur in rural areas than in urban areas [34].

2.7 Crossing facilities

Crashes involving pedestrians and cyclists occur frequently at facilities designed for pedestrians and cyclists such as pedestrian crossings, cycle tracks, and cycle lanes. This means that these facilities are not necessarily good enough to prevent crashes [34]. However, pedestrian crossings might also be the location at which roads are most often crossed.

In the United Kingdom, over 20% of crashes happen at a place where people should be safe, such as on the pavement or at a pedestrian crossing. In Denmark, half of the crashes with cyclists occur at facilities for cyclists such as cycle tracks or cycle lanes [34].

Pedestrian crashes occur most often whilst crossing the roadway, especially for older pedestrians. In the Netherlands, 25% of the pedestrian fatalities that died as a result of a crash while crossing the road, were crossing at a zebra or another kind of pedestrian crossing. Of the elderly, 75% of pedestrian fatalities died as a result of a crash whilst crossing the road. Of these, 38% were crossing the road at a pedestrian crossing (probably they are also more inclined to cross the road at a pedestrian crossing).

Pedestrian crashes often occur when people are trying to cross the street on links outside pedestrian crossings or where no pedestrian crossings exist. One of the causes is the driver's difficulty in perceiving pedestrians because of darkness and/or parked cars. In the United Kingdom, nearly 90% of the injuries to older pedestrians which are caused by motor vehicles happen under such conditions. In over 10% of cases, the driver cannot see pedestrians because of parked cars. 67% of pedestrians in the United Kingdom were killed or injured whilst crossing the road more than 50 metres away from a pedestrian crossing [34].

2.8 Contributory factors

Apart from general factors such as the speed of motorised vehicles, the weight and design of motor vehicles and the lack of protection of pedestrians and cyclists (see No speed, no mass and lack of protection), factors that have also been identified as causes of pedestrian and cyclist crashes are visibility, vehicle control, and alcohol consumption.

Lack of visibility is a factor in cyclist crashes. The fact that vulnerable road users are not always very well detected in the traffic plays a part, even in daytime. This is aggravated at dusk, dawn, and night, especially when public lighting is absent or weak. The most serious problem for cyclists seems to be detection of them by drivers approaching alongside or from behind. The limited physical visibility of cyclists (linked to their vehicle - car drivers are seeking for vehicles as big as theirs) is reinforced, at least in countries when cycling is not very common, by their lack of 'social visibility': car drivers do not see cyclists because they do not expect to see any [39].

The influence of technical defects of the bicycle, the quality of the road surface, and the presence of protective devices (such as cycle seats and wheel spoke covers) has been analysed in the Netherlands. A technical cycle defect was cited as the principal cause of the crash by 7% of cyclists aged twelve years and older. In most cases, the condition of the brakes was poor [43].

Several studies have indicated that alcohol consumption is a relevant factor in crash causation. Data from Clayton & Colgan [9] suggests that two thirds of pedestrians killed between 2200 and 0800 hours in one area had been drinking, and one third had BAC levels above 150 mg/100ml; it is concluded that risk increases significantly above this BAC level. In a Dutch study in Groningen (a Northern province) dealing with the period 1993-1997, some 5-10% of pedestrians had A&E treatment in the hospital related to alcohol consumption [33].

3. Measures to reduce crash numbers and injury severity

Long-term planning is needed to create the fundamental changes that will improve the safety and mobility of vulnerable road users. Measures require a framework that takes the various needs of vulnerable road users into account. Concepts like Sustainably Safe Traffic and Zero Vision provide the framework that long-term planning requires. These concepts stop defining road fatalities as a negative but largely accepted side-effect of the road transport system. Rather, road fatalities can and should be avoided, and the probability of crashes can be reduced drastically by means of the infrastructure design. Where crashes still do occur, the process which determines the severity of these crashes should be influenced in such a manner that the possibility of severe injury is virtually eliminated.

The Dutch Sustainably Safe Traffic system is currently characterised by:

- A structure that is adapted to the limitations of human capacity through proper design, and in which streets and roads have a neatly appointed function, as a result of which improper use is prevented.
- Vehicles which are fitted with facilities to simplify the driver's tasks and which are designed to protect the vulnerable human being as effectively as possible.
- Road users, who are adequately educated, informed and, where necessary, guided and restricted.

A road safety system based on this framework can be combined with transport policies that consider walking and cycling as a mode of transport, such as the one written down in UK's White Paper on *A new Deal for transport: better for everyone* [60].

The main consequences of the necessary framework and new concepts for road planning and design are:

- Motorised traffic with a flow or distribution function must be segregated from non-motorised transport.
- A network of main traffic routes must be created for pedestrians and cyclists.
- A fair balance between motorised and non motorised traffic for priority facilities at crossings should be achieved.
- The maximum speed of motorised traffic should be limited on roads where it mixes with non-motorised traffic [60].

Specific measures that are needed to realize the above mentioned traffic system, relate to road and traffic planning, and road design. In addition, there are other measures that could improve the safety of pedestrians and cyclists, such as:

- Improvement of the visibility of pedestrians and cyclists
- Pedestrian- and cyclist-friendly design of cars and heavy vehicles
- Bicycle Helmets, and
- Education and training.

3.1 Land use planning

Pedestrian safety measures that are the most comprehensive and most closely associated with urban planning and policy philosophies are:

- Area-wide speed reduction or traffic calming schemes, and
- Provision of an integrated walking network.

These are two complementary measures, which can be implemented together without conflicting. Not only do they apply to different parts of the urban fabric, but they also address different objectives. Area-wide schemes (the most widespread of which is the 30 km/h zone) are aimed at reducing vehicle speeds and thus at allowing for a safer mingling of pedestrians with motor traffic. Integrated walking networks (usually centred around a downtown pedestrian zone) serve to remove and/or reduce conflicts between pedestrians and vehicles and to provide or improve crossing points [60] [38].

The same basic planning principles that apply for pedestrians apply for cyclists. Because cycling is suitable for travel over greater distances than walking, it is necessary to distinguish a flow and an access function. As is the case with motorised traffic, a network for the flow function is required. However, this network cannot follow the network for through-motor traffic easily, since the mesh of the routes of the cycling network is smaller. Provisions for cycling should therefore not simply be seen as additional features of the traffic structure for motor traffic. Rather, they require a network of their own [60] [39].

When facilities for cyclists are being designed, five criteria are important if their needs are to be met [10]:

- Safety*:* for large parts of the population in Europe (the perception of) road safety problems is a key reason for not cycling. Improvement of the safety of cyclists on the road is therefore a precondition for promotion of cycling.
- Coherence*:* continuity, consistency of quality, recognizability and completeness. It is obvious that cycling will be restricted if the cycle network is not complete or coherent. These are mainly features at network level.
- Directness*:* mean travel time, detours and delays.
- Comfort*:* smoothness of road surface, curves, gradients, number of stops between starting point and destination, complexity of rider's task.
- Attractiveness*:* visual quality of the road, survivability, variety of environment and social safety.

3.2 Road design

Road design measures that assure a pedestrian-friendly and cyclist-friendly infrastructure, relate to:

- Area-wide speed reduction
- Safe walking routes
- Cycling networks
- Crossing facilities

The next four sections give a general overview of what they entail. More detailed information can be found in the ADONIS-manual [12] and in Design manual for bicycle traffic [10].

3.2.1 Pedestrian-friendly networks: area-wide speed reduction and safe walking routes

Area-wide speed reduction
Considering the relationship between collision speed and probability of death (see graph by Pasanen in Section 1.1), the probability of a fatal injury for a pedestrian reduces with decreasing collision speeds starting at a driving speed of about 80 km/h. At collision speeds below 30 km/h, encounters between motorised vehicles and pedestrians do not usually result in a fatality. One of the Sustainable Safety principles has been derived from this: where pedestrians and motorised vehicles meet, driving speeds of the latter must be reduced to 30 km/h.

In order to realize an area-wide reduction of driving speed in the short term, this speed reduction has to be forced on road users mainly by traffic engineering and infrastructural measures. Creating zones by road signs alone does not discourage drivers from driving faster than 30 km/h. Physical measures such as speed humps can force speed reduction [44], but can meet with opposition from bus and emergency vehicle drivers as well as from residents if extensive ground vibrations occur. In several countries, 30 km/h zones are implemented in residential areas or school zones. A Dutch evaluation of the effectiveness of these zones indicated that the introduction of these zones led to a reduction of about 10% in the number of fatalities per km road length and a reduction of 60% in the number of in-patients per km road length [57].

In the medium term, intelligent use of area-wide speed cameras might provide an alternative means of enforcement in some areas. In the longer term, extensive implementation of Intelligent Speed Adaptation should result in more direct compliance with speed limits.

Safe walking routes
'Kid routes' are special corridors of safe routes for guiding children for example to schools, play areas and sport facilities. These kid routes can mainly be found in busy residential areas. Since 2006 Delft and Amsterdam are the first municipalities in the Netherlands where children can use kid routes. The special child-friendly routes have a playful layout in which recognizable markings and boards lead children to their destination [11].

3.2.2 Cycling networks

Although cycle lanes have been found a good safety measure on road sections - provided the width of the track is sufficient and measures have been taken to prevent crashes with vehicles parking - there is evidence that they tend to create safety problems at intersections. Particular attention has to be given to the design of cycle routes at these locations. Crossings between cycle tracks and streets do not always seem well understood by drivers, in particular, when environmental features do not clearly reflect the right-of-way, thus creating confusion among drivers and cyclists alike [39]. Additional facilities are necessary at intersections in order to reduce the speed differences between cyclists and other traffic as much as possible. Priority regulations, speed humps, and raised intersections are suitable to achieve this [47].

3.2.3 Crossing facilities

Introducing crossing facilities does not necessarily reduce pedestrian and cyclist casualties. They need to be carefully designed and appropriately sited if they are to improve safety. Crossings at inappropriate sites can lead to confusion and unsafe behaviour by both motorists and pedestrians [33] [60].

Feelings of mutual respect can be promoted by right-of-way regulations, speed reduction measures and improved visibility. Examples of speed reduction measures at cyclist crossings are raised cycle crossings, humps, refuges in crossings, and mini roundabouts. Important features for improvement of visibility are: truncated cycle tracks, advanced stop lines at signalised intersections, and parking regulations [60] .

Features of safer pedestrian crossings, in particular to allow for the specific limitations of the elderly pedestrian, include:

- Reducing the distance to be crossed by means of a median island and/or by sidewalk extensions;
- Equipping more pedestrian crossings with traffic lights;
- Allowing for the slower walking speed of the elderly when setting the traffic lights cycle;
- Reducing the speed of other traffic or banishing motorised vehicles completely in areas with many pedestrians [49].

At facilities used by both pedestrians and cyclists there must be only one rule: either both have priority, neither have priority, or both have traffic lights. Where they do have priority, this can be indicated by triangular priority marking just in front of the crossing facility, combined with an extended speed hump to ensure a low approaching speed. A quite long speed hump would slightly increase motorists' comfort because they can position the whole vehicle on the speed hump just in front of the crossing facility [48].

There is much to be said in favour of combining crossing facilities for pedestrians and cyclists, because a greater number of people crossing at one time reduces risk (see Risk and measurement of exposure). One possible method is the ‘Toucan crossing’ currently used in Great Britain [42] (see Figure 4). This crossing facility is named Toucan because both pedestrians and cyclists can use the same facility (‘two can cross’). The advantage of a combined crossing is that it is more visible for fast-moving traffic travelling on the major road. In addition, Toucans can detect the numbers of crossing pedestrians and cyclists. These systems enable a fairer distribution of waiting times for fast and slow traffic, and they often establish shorter waiting cycles.

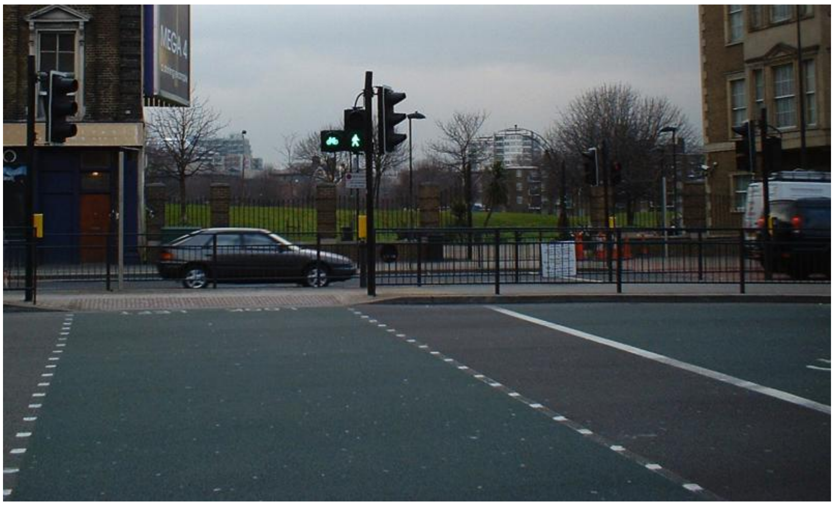


Figure 4 Toucan crossing. Source: C. Ford

3.3 Visibility: lighting and reflecting devices

Both child pedestrians and cyclists benefit from conspicuity aids and the use of light-coloured and retro-reflective clothing. Designers and manufacturers of children’s clothing and accessories are well-positioned to incorporate retro-reflective materials into product lines. Parents, as well as public health and safety officials should encourage them to do so, as one component of an ongoing campaign for protecting children in traffic. Dangle tags, armbands, strips on school bags, and use of bicycle lamps are all recommended [35] [34].

To ensure the visibility of the cyclist, a bicycle should be equipped with a red reflecting device at the rear, devices ensuring that the bicycle can show white or selective yellow light in front, and red lights on the rear. In some countries, reflectors are also compulsory on the wheels, at the front, and on the pedals (see Vehicle regulations). However, not all bicycles meet those legal norms. A Dutch survey showed that 37% of cyclists did not have their lights on during darkness [4] . Similar results were found in a Scandinavian survey: 35% of the cyclists did not have correct lighting [26].

3.4 Vehicle design of crash opponents

Injuries to cyclists and pedestrians can be reduced by better design of cars and heavy vehicles. Design measures include crash-friendly car fronts, and side-underrun protection on lorries [60].

Attention to the development of crash-friendly car fronts takes place at the European level. It is a step in the right direction that current test requirements for crash-friendly car fronts take into account the points of the body where pedestrians hit cars. However, the test requirements are not as comprehensive as they could be [21], and they do not take sufficient account of cyclists. In a crash, cyclists hit at a different place on a car front than pedestrians do. Tightening up the test requirements is therefore desirable [44].

Lorries could be made much safer for third parties by the application of adequate protection around the vehicle. Such protection prevents the dangerous underrun of, for instance, cyclists and other two-wheeled vehicles. In 35-50% of the crashes between heavy goods vehicles and two-wheelers, injury severity can be limited by side-underrun protection. Moreover, this facility prevents a road user involved in the collision still being run over. The number of traffic fatalities in urban areas due to crashes of this type could be reduced by 10% [25]. For moped riders, cyclists and pedestrians, closed side-underrun protection on lorries is more effective than open protection. Both open and closed side-underrun protection appear in the top ten of relevant and cost-effective measures to reduce the number of casualties as a result of crashes involving lorries [29] (see PROMISING [40] for a cost-benefit analysis).

3.5 Protective devices: helmets

The only protective device available for pedestrians and cyclists is the bicycle helmet. It can prevent head injuries in case the cyclist falls. Some countries have legislation on helmet wearing (see Bicycle helmet legislation), whereas others are against governmental promotion of helmet use. The latter claim that official promotion of helmets could have the negative effect of incorrectly linking cycling and danger. This could result in a decrease in bicycle use, which is contrary to their policy to promote cycling (see Pros and cons regarding bicycle helmet legislation). To prevent helmets having a negative effect on the use of bicycles, the best approach might be to leave the promotion to the manufacturers and shopkeepers.

3.6 Education and training

Education goes together with a comprehensive approach to road safety and mobility. Crucial factors for safe behaviour are [60]:
- Control of the vehicle by handling skills and defensive behaviour,
- Control of situations by understanding of road conditions
- Understanding and communication among road users, and
- Behavioural patterns.

Some examples are described concerning road safety education for children. Education should, however, also be directed at other types of road users, such as motorists.

3.6.1 Road safety education for children

Young child pedestrians learn best at the roadside or a close approximation. From there, with experience, they develop conceptual understanding. This supports the promotion of practical skills training for pedestrians, cyclists, and drivers in connection with reflections on emerging ideas and understanding. In addition to skills acquisition, improvement of knowledge and attitudes is implicit in most of the recently developed behavioural programmes [35].

There is general consensus in the research and among practitioners that ad hoc activities, such as visits from experts and road safety enthusiasts, may have mass appeal but are relatively unsuccessful because road safety education should be planned and progressive.

Such activities should be used as additions to the road safety programme. Bailey (1995) promotes integrated road safety education that spans several curriculum areas and this approach is also supported by the Good Practice Guidelines for Road Safety Education in Schools (www.dft.gov.uk) which identify and provide examples of road safety education across the curriculum and recommend that road safety professionals support teachers in delivering a progressive programme of road safety education rather than occasional talks on road safety [35].

Duperrrex, Bunn and Roberts [13] reviewed the literature on the education of pedestrians for injury prevention. They identified 15 studies of sufficient quality (i.e. random assignment to the treatment group, and the use of a control group). Of these studies, 14 were aimed at children. None of the studies looked at the effect of safety education on the occurrence of pedestrian injury, but six assessed its effect on behaviour. The effects varied considerably across studies and outcomes, indicating that the impact of programmes differ. So, evaluation studies may encourage programme developers to enhance the effectiveness of programmes.

3.6.2 Education for other road users

The potential contribution of education to the safety of pedestrians and cyclists depends on more than just the education of themselves. Education has an important role to play in creating cooperation between road users and enabling them to adapt to each other. For this reason, car driver instruction should cover characteristics of pedestrians' and cyclists' behaviour and the necessary anticipation required by drivers to avoid conflicts with them. Two central themes for an instruction programme are recommended in this respect: adaptation of speed, and learning to understand other road users and to 'communicate' with them [60].

4. Promote cycling and bicycle helmets or not?

Two aspects of government policy that might lead to debates are promotion of cycling and promotion of bicycle helmets. Both topics are discussed in this chapter.

- Promoting cycling: changes to expect
- Pros and cons regarding bicycle helmet legislation

4.1. Promoting cycling: changes to expect

Promoting cycling as an alternative to short car trips has several advantages: it contributes to health, it reduces pollution through noise and exhaust emissions, and it reduces congestion problems. A drawback of promotion of cycling might be an increase in crash rates.

- Effects on crash rates
- Health effects
- Environmental effects
- Cost –benefit analysis

4.1.1 Effects on crash rates

In general, the expected number of crashes is the product of exposure and crash rate. Therefore, one would expect that an increase in the number of cyclists - as a result of the promotion of cycling - would increase the number of crashes. However, it is increasingly recognised that the crash rate is also related to the amount of cycling per inhabitant; it has been shown that the fatality rate for cyclists varies in inverse proportion to the amount of cycling per cyclist. In countries where people cycle a lot, cyclists have a lower fatality rate. A similar inverse relationship exists for the number of pedestrians or cyclists crossing at intersections. Summersgill et al. [46] have shown that for pedestrians crossing at intersections, increasing pedestrian flows result in lower crash rates per crossing pedestrian [60] [40].

Several factors may account for the tendency of crash rates to decline as the amount of exposure increases. In the first place, as each cyclist accumulates more kilometres, he or she becomes more experienced and more aware of the hazards of traffic. In the second place, when cyclists become more numerous in traffic, drivers of motor vehicles become more aware of the presence of cyclists and may behave more considerately towards them. In the third place, countries where cycling is common, like Denmark or the Netherlands, are likely to provide better facilities for cyclists than countries where cycling is less common [40]. Similarly, increased numbers of cyclists in other countries will result in more and better cyclist facilities.

4.1.2 Effects on health

The beneficial effects of cycling on health have been assessed in terms of prevention of cardiovascular risk. In a study of 9,400 men in sedentary occupations (executive grade civil servants), 70% cycled at least an hour a week to work or at least 25 miles of other cycling a week. They were found to have an incidence of coronary heart disease of 2.5 per 1000 man years. This compares with 5.6 for non-cycling civil servants. Those cycling less kilometres had a rate of 4.5 [17]. This health aspect is 5 to 10 times more important than the safety aspect. ECF [15] cites Hillman (1993), who calculated that years of life gained by cycling outweigh years of life lost in crashes by 20 to 1 [39].

4.1.3 Environmental effects

Motorised forms of transport cause pollution through noise and exhaust emissions. Cycling and walking do not produce such emissions. The table below gives some estimated effects of replacing car kilometres with cycle kilometres.

Estimated effects of a one-third reduction in the number of car trips from 44% to 30% of all trips in a city:

- 30% less traffic jams,
- 25% reduction in pollution from motor vehicles (all types),
- 36% reduction in carbon monoxide (CO) emissions,
- 37% reduction in hydrocarbon emissions (CH) by private cars only,
- 56% reduction in nitrogen dioxide (NO_2) emission,
- 25% reduction in petrol consumption (cars only),
- 9% reduction in the number of people suffering from noise pollution,
- 42% reduction of the barrier effect of major highways.

Source: The above figures are estimations in the 1980s of the effects of a pro-bicycle policy in Graz, Austria (252,000 inhabitants; cited by EC DGXI, 1999).

A Cyclists' Public Affairs Group study [17] has demonstrated that modest increases in cycling could readily reduce transport sector emissions by 6% of the total in Great Britain, while at Dutch levels there would be a 20% reduction.

Car traffic is moreover the major source of noise in towns. In France, since 1 January 1998 any renovation or construction of urban thoroughfares must include provision for cyclists. In addition, all conglomerations in France with more than 100,000 inhabitants had to adopt an urban mobility plan. The purpose of this is to reduce pollution-producing town traffic [39]. Energy savings would also be an important benefit of increased level of cycling. The space consumption of a cyclist was calculated to be only 8% of the space consumption of a car UPI report Heidelberg 1989, cited by EC DGXI [14].

4.1.4 Cost-benefit analysis of mode switching

Cycling does not impose the same external costs on society as car driving does. The major external costs of car driving include:

- Air pollution
- Traffic noise
- Traffic congestion, and
- Injury crashes.

The major external costs of cycling are the costs of injuries. However, contrary to car driving, cycling may also generate benefits for society. These may include, for example, savings in public health care as a result of improved physical fitness.

In the PROMISING project [40], a cost-benefit analysis was carried out of switching from driving a private car to cycling. External costs that were included in the calculation were air pollution, traffic noise, 40% of the costs of crashes, and savings from reduced absence from work. The researchers concluded that despite the fact that crash costs of cycling are higher than those of car driving, the total social costs of cycling are lower than those of driving a car.

4.2 Pros and cons regarding bicycle helmet legislation

Although bicycle speed is rather limited, it is acknowledged that a properly designed helmet provides very good protection for the most vulnerable part of the body, the head, from being severely injured in a crash. Whereas the helmet is more or less compulsory in all countries for participants in sporting events, in most countries it is still optional for cycle touring or bicycle rides in general (see Bicycle helmet legislation for exceptions). Some cyclists are against the helmet as it imposes a requirement conflicting with the feeling of freedom given by the bicycle or because it is unsightly, uncomfortable, or unnecessary over short distances. Others are firmly in favour of it as it provides good head protection [16].

In 2000, helmets were worn on a voluntary basis by 15% of cyclists in Finland, 16% in the United Kingdom, 17% in Sweden, 7% in Switzerland and 6% in Norway. In Denmark, 68% of children, who are passengers on bicycles (children between 0 and 5 years old), were using helmets. 34% of the children between 6 and 9 years old use helmets on their bicycles. Only 5% of cyclists aged between 10 and 25 year old used a helmet, and among cyclists aged 25 years and older only 3% used a helmet. The proportion is insignificant in most other countries [16].

Several reviews have been conducted on the effectiveness of bicycle helmets in reducing head and facial injuries [54] [53] [41] [30] . Studies over the last 15 years in the United States, Europe, Australia and New Zealand indicate that bicycle helmets are very effective in decreasing the risk of head and brain injuries. Critics of legislation, though, have pointed out that reductions in absolute numbers of cycling fatalities and severe head injuries can be at least partially explained by a decrease in cycling per se. Given that good evidence exists that regular cycling is associated with considerable health benefit, and that the benefits heavily outweigh the risk of injury, there is understandable concern about legislation resulting in a reduction of cycling levels.

Additionally, there is a broader debate about whether helmet use is the best way to improve the safety of cyclists. An alternative approach to this issue is adopted in the Netherlands. The Dutch government, private safety organizations and cyclists' groups all tend to agree on the following propositions: Promoting the use of bicycle helmets runs counter to present government policies that are aimed at the primary prevention of crashes (as opposed to secondary prevention) and at stimulating the use of the bicycle as a general health measure. Attempts to promote bicycle helmets should not have the negative effect of incorrectly linking cycling and danger. Nor should the promotion of helmets result in a decrease in bicycle use. Because of these considerations, a mandatory law for bicycle helmet use has not been thought an acceptable or appropriate safety measure in the Netherlands [59].

Towner et al. [54] have summarised the pros and cons of bicycle helmet legislation as follows:

- The pro-bicycle helmet group base their argument on the fact that there is scientific evidence that, in the event of a fall, helmets substantially reduce head injury.
- The anti-helmet group base their argument on several issues including: compulsory helmet wearing leads to a decline in cycling, risk compensation theory negates health gains, scientific studies are defective, and the overall road environment needs to be improved.

5. Special regulations for pedestrians and cyclists

Pedestrians and cyclists are both subject to the traffic rules defined in the Vienna Convention. In some countries, additional rules have been defined, for example relating to protective or reflecting devices. As rules and regulations differ for pedestrians and cyclists, they will be discussed in separate paragraphs.

- Traffic rules for pedestrians
- Traffic rules and regulations for cyclists and their vehicles

5.1 Traffic rules for pedestrians

In addition to the rules which normally apply to all public highway users, according to the Vienna Convention, pedestrians are subject to specific rules defined in their national legislation in order to ensure that they can travel safely and easily:

- If, at the side of the carriageway, there are pavements (sidewalks) or suitable verges for pedestrians, pedestrians shall use them. Nevertheless, if they take the necessary precautions:
  (a) Pedestrians pushing or carrying bulky objects may use the carriageway if they would severely inconvenience other pedestrians by walking on the pavement (sidewalk) or verge;
  (b) Groups of pedestrians led by a person in charge or forming a procession may walk on the carriageway.
- If it is not possible to use pavements (sidewalks) or verges, or if none is provided, pedestrians may walk on the carriageway; where there is a cycle track and the density of traffic so permits, they may walk on the cycle track, but shall not obstruct cycle and moped traffic in doing so.
- Pedestrians walking on the carriageway shall keep as close as possible to the edge of the carriageway.
- It is recommended that domestic legislation should provide as follows: pedestrians walking on the carriageway shall keep to the side opposite to that appropriate to the direction of traffic except where to do so places them in danger. However, persons pushing a cycle, a moped or a motor cycle, and groups of pedestrians led by a person in charge or forming a procession shall in all cases keep to the side of the carriageway appropriate to the direction of traffic. Unless they form a procession, pedestrians walking on the carriageway shall, by night or when visibility is poor and, by day, if the density of vehicular traffic so requires, walk in single file wherever possible.
- Pedestrians wishing to cross a carriageway:
  (a) Shall not step on to it without exercising care; they shall use a pedestrian crossing whenever there is one nearby.
  (b) In order to cross the carriageway at a pedestrian crossing signposted as such or indicated by markings on the carriageway:
    (i) If the crossing is equipped with light signals for pedestrians, the latter shall obey the instructions given by such lights;
    (ii) If the crossing is not equipped with such lights, but vehicular traffic is regulated by traffic light signals or by an authorized official, pedestrians shall not step onto the carriageway while the traffic light signal or the signal given by the authorized official indicates that vehicles may proceed along it;
    (iii) At other pedestrian crossings, pedestrians shall not step on to the carriageway without taking the distance and speed of approaching vehicles into account.
  (c) In order to cross the carriageway elsewhere than at a pedestrian crossing signposted as such or indicated by markings on the carriageway, pedestrians shall not step on to the carriageway without first making sure that they can do so without impeding vehicular traffic.
  (d) Once they have started to cross a carriageway, pedestrians shall not take an unnecessarily long route, and shall not linger or stop on the carriageway unnecessarily.

(UNECE, 1993 [55])

5.2 Traffic rules and regulations for cyclists and their vehicles

The traffic-related rules and regulations that are applicable to cyclists can be divided into vehicle regulations, regulations regarding the use of cycle helmets, and traffic rules.

5.2.1 Vehicle regulations

According to the Vienna Convention, a cycle is a vehicle with at least two wheels that is propelled solely by the muscular energy of the person riding on that vehicle, in particular by means of pedals or hand-cranks. Furthermore, the Convention states that a cycle shall: a) have an efficient brake, b) be equipped with a bell capable of being heard at a sufficient distance, and carry no other audible warning device, and c) be equipped with a red reflecting device at the rear, and devices ensuring that the bicycle can show a white or yellow light at the front and a red light at the rear [55].

In addition to the abovementioned “conditions for the admission of cycles to international traffic”, some countries such as Germany and the Netherlands have supplementary regulations regarding mandatory equipment to ensure cyclists’ visibility. Examples are:

- One white reflecting device visible from the front.
- Orange pedal reflectors visible from the front and rear.
- Two wheel-mounted orange spoke reflectors on each wheel, arranged at an angle of 180° and visible from the side, or continuous white circular retro-reflector strips on the tyres or on the spokes of the front and rear wheels.
- One additional red large-surface reflector on the rear.
- Mudguards to prevent mud from reducing the visibility of lights and reflectors.

In some countries (the Netherlands, for example), standards for accessories such as children’s bicycle seats have been drawn up. These standards include requirements and recommendations regarding seat attachment, dimensions, footrests, and protection against feet coming into contact with the spokes [16] .

5.2.2 Bicycle helmet legislation

In some European countries, cycle helmets have become mandatory in the last few years. In Malta, cycle helmets became mandatory for all cyclists in April 2004. In Sweden, cycle helmets became mandatory for children up to 15 years of age on January 1st 2005. The same group of cyclists has to wear helmets in Slovenia and the Czech Republic. In Spain, cyclists have to wear a helmet outside urban areas except when going uphill [22] .

The definition of precise standards without which the effectiveness of helmets cannot be guaranteed, is a prerequisite for any regulations on the wearing of helmets. Some countries have already set up such norms. The European Directive No. 89/686/EC on personal protective equipment lays down the standards which could be adopted for cyclists’ helmets. The provisions for children’s helmets, however, still have to be settled [16].

5.2.3 Traffic rules for cyclists

In addition to the rules which normally apply to all public highway users and in accordance with the Vienna Convention, cyclists are subject to specific rules defined in their national legislation in order to ensure that they can travel safely and easily:

- Cyclists must not ride without holding the handlebars with at least one hand, must not allow themselves to be towed by another vehicle, and must not carry, tow, or push objects which hamper their cycling or endanger other road users.

- They must keep to the right of the carriageway (to the left in the United Kingdom and Ireland) and give an appropriate arm signal when they wish to turn.
- In principle, cyclists may not ride more than one abreast. Some countries however introduced exceptions to this rule; for instance, cyclists may ride two abreast where the carriageway is wide enough, where cycle traffic is heavy, on cycle tracks, etc.
- They are required to use cycle lanes and tracks. They may not, however, use motorways and similar roads.
- When walking and pushing their bicycles on foot, cyclists are classified as pedestrians and may therefore use the pavement [16].

The Vienna Convention prohibits the *transport of passengers* on bicycles, but enables the Contracting Parties to authorise exceptions. In some countries, the transport of a passenger is allowed only if he is under a statutory age limit (for instance 14 years in France) and if the cyclist himself has a minimum age [16].

Germany has recently added new elements to its traffic code for cyclists. Since then, cyclists are allowed to ride contraflow in selected one-way streets, and in so-called bicycle streets cyclists may make use of the whole street whereas cars have to stay behind the cyclists. As in some Scandinavian countries, cycle tracks in Germany can be made compulsory only if they meet appropriate minimum quality standard, otherwise cyclists may choose not to use cycle tracks [60].

Some national legislations provide that cyclists can only ride on a road after a certain age. In Switzerland, a cyclist must have at least the legal age to go to school before he can ride on a road. In Denmark, children under the age of 6 are not allowed to go by bicycle unless they are escorted by a person who is 15 years old or older. In Germany, children must be at least 8 years old with the same provisions as in Denmark. In Poland, children over 10 years must have passed a test to be allowed on a road [16].

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Best practice to promote cycling and walking (Dijkstra et al., 1998)

This pdf-document contains information about measures which are intended to stimulate cycling and walking so that the number of short car trips will be reduced. In general, two kinds of measures are presented: technical and non-technical measures which are friendly for pedestrians and cyclists. Examples of the first category are good cycle tracks and good crossing facilities. The second kind of measures concern rules and regulations, traffic signals, and public information and education. Each description of a measure is accompanied by illustrations: photos, diagrams of layout designs or other road elements, or illustrations of public information material. Infrastructure measures are sometimes provided with dimensions as well. Next, the advantages and disadvantages of the measures in terms of comfort, costs, safety, and social safety are described in as much detail as possible. Also discussed are the advantages and disadvantages for road users other than pedestrians and cyclists. If possible, a cost estimate is provided. Finally, the names of publications or organisations are listed as sources for more information.

The pdf-document is one of the reports of the ADONIS research project. The original title of the project is: Analysis and Development Of New Insight into Substitution of short car trips by cycling and walking. The ADONIS project was commissioned by European Commission as part of the Fourth Framework Programme, and ran from 1 may 1996 until end of 1997.

Design manual for bicycle traffic (CROW, 2007)

This design manual replaces 'Sign up for the bike' (CROW, 1993). It offers road designers and other interested parties extensive data on how to attain a bicycle-friendly infrastructure. A bicycle-friendly infrastructure is one that allows direct and comfortable cycling in a safe and attractive traffic environment. Only then is it possible to compete with the car. High quality bicycle infrastructures lead to a larger share of bicycles in the modal split. This design manual describes the steps required to achieve such an infrastructure, from the policy plan to promote cycling to the physical implementation of a bicycle-friendly infrastructure.