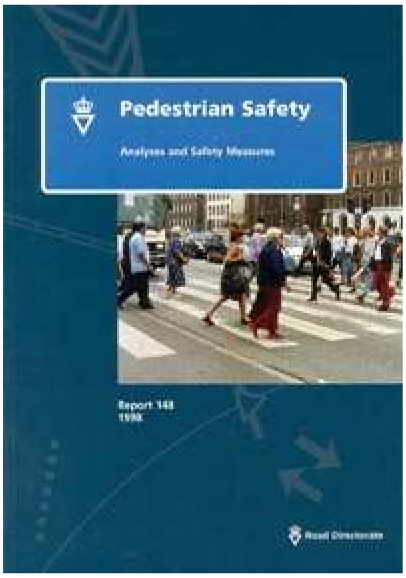
Pedestrian Safety

Analyses and Safety Measures
Report 148
1998



Content

Abstract

In the period 1986-95 the number of pedestrian casualties decreased by 26% in Denmark.

But since 1981 up to 1993-95 the risk of being killed or injured per walked km has only decreased 8%, due to a decline in walking as a mode of transport. However, the 8% is slightly uncertain. Walking as a mode of transport is - according to the official statistics collected by the police - about 8 times (trips shorter than 300 metres are excluded) as dangerous per person km as travel by private cars and just as dangerous as cycling. If the risk instead is worked out per trip or travelled hour, walking is actually safer than both the private car and cycling.

Elderly pedestrians over 74 years of age has a very high risk of being killed compared to younger pedestrians. It is also much more dangerous to walk in darkness than in daylight, especially in rural areas. Since 20% of the killed pedestrians are under the influence of alcohol, it is safe to say that drunk pedestrians also is a high risk group. About 75% of pedestrian accidents happens when pedestrians are crossing the road. The largest challenge is therefore to reduce the risk for crossing pedestrians.

Based on a literature study and analyses of Danish pedestrian accidents a list of attained and estimated safety effects for pedestrians when implementing safety measures is presented. Among these measures are zebra crossing, pedestrian refuge and roundabout.

Foreword

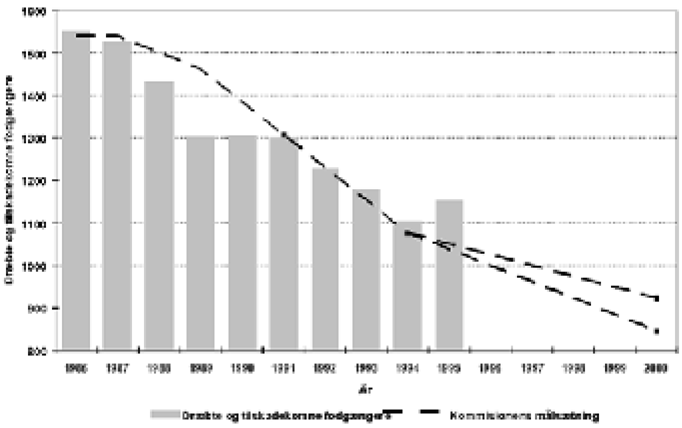
With its fundamental point of departure in the years 1986-1987, the Danish Road Safety Commission's Action Plan has the objective of reducing the number of casualties in traffic by 40-45% before the end of the year 2000. By the end of 1995, the number of casualties in traffic had dropped by 21%, whereas the number of casualties among pedestrians had dropped by 25%, i.e., the drop among pedestrians was greater than for road traffic in its entirety. However, accidents in which pedestrians are involved are extremely serious. Every fifth person killed on the roads is a pedestrian. Travel surveys show that the Danish population as a whole walks fewer and fewer kilometres. This means that the risk of walking a single kilometre in road traffic has not decreased at the rate indicated by the accident trend. In fact, these surveys indicate that the risk has dropped only marginally. Taken as a whole, it is important that new analyses of pedestrian safety should be carried out.

In this report, pedestrian safety is illustrated from four different angles, i.e., safety of pedestrians considered in relation to other modes of transport, the trend over the last 10 years, the status for 1993-1995 and the safety effects of facilities for pedestrians, such as footways, footpaths, lighting and zebra crossings. A number of analyses of accidents involving pedestrians is included. The last part of this report indicates problems of pedestrian safety where new research and development are necessary.

Unless other sources are given the analyses are based on information taken from the accident base of the Danish Road Information System (VIS), which stores all accidents recorded by the Danish police. Pedestrians are classified as two types of element in the system, i.e., ordinary pedestrians and pedestrians on wheels, such as on roller skates or in perambulators. Both types of element are included in the analyses.

1. Introduction

Road accidents and their consequences are a significant social problem. In 1995, the police reported 582 fatalities, 5,642 serious injuries and 4,367 slight injuries on Danish roads. Of these, pedestrians accounted for 118 fatalities, 716 serious injuries and 317 slight injuries. Thus, every fifth person killed on the roads is a pedestrian. In Denmark, the police only record pedestrian accidents in which at least one vehicle was also involved. The police do not record single accidents, such as falls.



The Danish Road Safety Commission's Action Plan was published in 1988. This plan contained a clear goal: the number of casualties was to be reduced by at least 15% by the end of 1991, by an additional 15% by the end of 1994 and by at least 10-15% more by the end of 2000. The baseline for the attainment of this goal is the years 1986-1987. The goal is absolute, i.e., it must still be attained in the event of changes in traffic conditions, such as increasing traffic volumes. Furthermore, it is a quantitative goal, which means, for instance, that no attempt will be made to attain it in certain groups of road user in preference to other groups.

Figure 1 illustrates the targets together with trend in the number of pedestrian casualties. The figure shows a marked drop in the number of casualties among pedestrians. Since the baseline years, 1986-1987, the number of pedestrian casualties has dropped by 25%. Up to and including 1994, the trend pointed in the right direction, although the number of pedestrian fatalities and casualties increased in 1995 so that the trend started to fall behind the target curve.

The problems associated with pedestrian safety are far greater than are reflected by the official statistics. For several years, the Accident Analysis Group at Odense University Hospital has kept an account of the extent to which the police record road accidents involving casualties in the hospital's area. For the years 1990-1994, 33-42% of pedestrian casualties in accidents with motor vehicles were recorded by the police (Accident Analysis Group, 1991-1995). The large deviations are due to the relatively modest input data, but there is nothing to indicate that the extent of recording has changed. This indicates that there is a real drop at the national level in the number of pedestrian casualties. On the basis of the figures from Odense University Hospital, the number of pedestrian casualties in accidents involving motor vehicles in Denmark in 1995 is estimated at approximately 3,000, while the number of casualties in connection with falls in Danish traffic areas in 1989 can be estimated at about 8,500 (Accident Analysis Group, 1991-1995; Zilmer, 1992). The number of falls has probably increased significantly since 1989, as the number of accidents involving roller skaters increased by 72% over the period 1991-1995 (Ministry of Transport, 1997). In 1995, 543 roller skaters were treated at five casualty wards, the areas of coverage of which comprised 14% of the Danish population.

National travel surveys show that, taken as a whole, Danes are walking fewer and fewer kilometres. The underlying reasons for the drop in casualties among pedestrians should be seen in the context of the drop in the number of walked kilometres. These surveys are presented in more detail in Chapter 2 of this report.

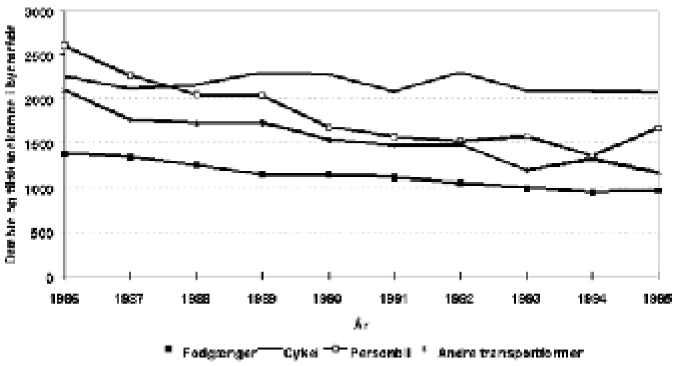
The Government's overall traffic plan, Traffic 2005, stresses that more energy-efficient and environmentally-friendly modes of transport should be promoted. More specifically, there is a desire to promote the use of public transport, cycling and walking through improvements to these alternatives. If the number of walked kilometres increases it could become still more difficult to attain the Danish Road Safety Commission's goal, as pedestrian risk is unchanged. This is one reason why new analyses of pedestrian safety are necessary.

2. Road safety across modes of transport

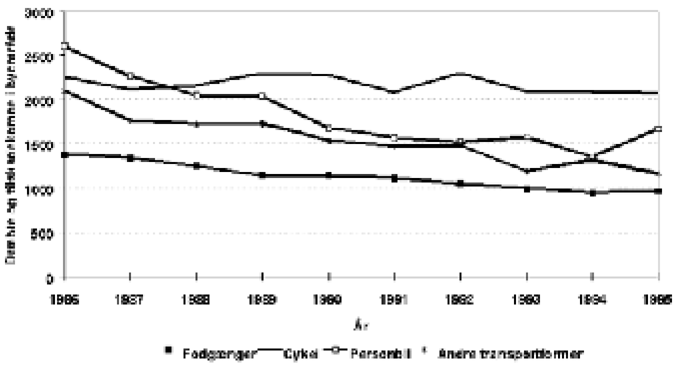
The Government's overall traffic plan, Traffic 2005, operates with a strategy in which the use of more energy-efficient and environmentally-friendly modes of transport should be promoted. The Government will work to transfer 4% of all private car kilometrage to cycling or walking before the year 2005. It is vital in this context to clarify risk differences and risk trends, distributed over different modes of transport.

2.1 Trend in casualties

Figure 2 and 3 show the trend in casualties in Danish road traffic by mode of transport for urban areas.



During the period 1986-1995, pedestrians accounted on a year-by-year basis for about 17% of all casualties in urban traffic. The proportion of cyclists has been increasing. Thus, cyclists accounted for 27% of all casualties in urban traffic in 1986, but as much as 35% in 1995. This indicates clear differences in casualty trends. In rural areas, the trend in casualties has been less favourable for all modes of transport. Motorists account for a far greater proportion of casualties in rural areas than in urban areas.



The drop in casualties has been slightly greater for motorists and other modes of transport than for pedestrians, while the number of cyclist casualties remained unchanged during the period 1986-1995. The reasons for the drop in the number of casualties are not the same for the individual modes of transport, as can be seen from the next section.

2.2 Trends in person kilometrage and own risk

Several national travel surveys have been conducted in Denmark. Only two of these surveys are cited, as the methodological differences between the surveys make them difficult to compare. For the same reason, the figures in the table contain uncertainties. The travel surveys are described in more detail in Annex 1.

16 year and over Mode of transport	Person km, bn, 1981	Person km per year, bn, 1993-95	Casual-ties 1981	Casualties per year, 1993-95	Person km % change	Casualties% change	Own risk % change
Pedestrian	1.5	1.2	1,276	940	- 20%	- 26%	- 8%
Bicycle	2.0	2.2	1,784	2,009	+ 12%	+ 13%	+ 1%
Private car	26.7	37.3	5,337	4,270	+ 40%	- 20%	- 43%

Table 1. *Person kilometrage and casualties in 1981 and 1993-95 for persons aged 16 years and over by mode of transport. Source: Police recorded accidents 1993-95; Danish Bureau of Statistics, 1982a and 1982b; National travel survey 1993-95 + May 1997; National travel survey of children and the elderly 1993-94.*

In the context of this report, "own risk" denotes the risk to the individual of being injured (slightly, seriously or killed) in relation to the level of exposure (number of kilometres or hours travelled or number of trips undertaken). In Table 1, own risk is expressed as casualties/person kilometrage and it shows the average value for drivers and passengers aged 16 years and over. Table 1 shows that the own risk for pedestrians has dropped by about 8% during the period 1981 to 1993-1995. This figure is, however, somewhat uncertain. The own risk for cyclists has remained almost unchanged over the same period, whereas the own risk for car occupants has dropped by about 43%. In other words, there has been a tendency to a decline in the own risk for pedestrians.

In the travel survey from 1993-1995, it was not possible to determine the number of trips nor the mode choice for trips of less than 300 metres. In Table 1, therefore, these trips have been estimated on the basis of the information on trips of less than 300 metres during 1995-1996, and on the mode choice, adduced in the travel survey from May 1997. During that period, trips of less than 300 metres were distributed, e.g., as 64.6% on foot, 16.7% by bicycle and 16.2% by car, which means, for instance, that about 37% of all trips on foot are of less than 300 metres. Thus, the figures for trips of less than 300 metres during 1993-1995 are somewhat uncertain since they are based on the information of mode choice for a single month.

2.3 Risk indicators
The own risk for persons aged 6 years and over is shown in Table 2, for pedestrians, cyclists and car occupants. The own risk is calculated on the basis of 24,110 police recorded casualties and 43,847 interviews in the national travel survey of 1993-1995, and the travel survey of children and the elderly of 1993-1994. A description of the method of calculating own risk can be found in Annex 1.

6 years and over	Casualties per million **person km**	Casualties per million **trips**	Casualties per million **person hours**
Pedestrian	1.0	1.7	5.4
Bicycle	0.81	2.4	11.3
Driver of private car	0.10	1.5	5.6
Passenger of private car	0.15	2.6	7.5
Private car	0.12	1.9	6.2

Table 2. *The own risk for persons aged 6 years and over for the years 1993-95 by mode of transport. Own risk has been calculated on the basis of accidents recorded by the police. Trips of less than 300 metres are not included. Source: Police recorded accidents 1993-95; National travel survey 1993-95; National travel survey of children and the elderly 1993-94.*

The choice of exposure is crucial to any comparison of own risk across different modes of transport. The reason for this is that the speeds and durations of the individual trips differ between the various modes of transport.

Walking and cycling are about 7 to 8 times more dangerous per person kilometre than is travel by private car, whereas travel by private car is more dangerous per trip than walking. Cycling is twice as dangerous per person hour travelled relative to walking and private car travel. If trips of less than 300 metres are included, the number of casualties per million pedestrian trips drops to 1.1 (instead of 1.7). The other figures of the table do not change significantly if trips of less than 300 metres are included.

The own risk figures of Table 2 were calculated on the basis of police recorded casualties. Own risk in Table 3 is calculated on the basis of casualties recorded by hospitals, i.e., allowance has been made for the percentage of casualties recorded by the police. If the police were to record all casualties occurring in traffic on Danish roads, the own risk figures would probably be equal to the figures of Table 3.

In 1994, the Odense police recorded 38.8% of all pedestrian casualties, 6.4% of cyclist casualties and 35.8% of car occupant casualties (Accident Analysis Group, 1996). If pedestrians' single accidents (falls) on roads, streets, squares, footways, footbridges, underpasses and other traffic areas are included, the police only recorded about 10% of pedestrian casualties (Zilmer, 1992; Accidents Analysis Group, 1990-1991). About 70 to 75% of all pedestrian casualties are falls.

6 years and over	Casualties per million **person km**	Casualties per million **trips**	Casualties per million **person hours**
Pedestrian	3 (10)	4 (17)	14 (54)
Bicycle	13	36	176
Driver of private car	0.3	4	16
Passenger of private car	0.4	7	21
Private car	0.3	5	17

Table 3. *The own risk for persons aged 6 years and over for the years 1993-95 by mode of transport. Own risk has been calculated on the basis of accidents recorded by hospitals. Trips of less than 300 metres are not included. NB: The figures in parentheses represent own risk including pedestrians' falls. Source: Police recorded accidents 1993-95; National Travel Survey 1993-1995; National travel survey of children and the elderly 1993-1994; Accident Analysis Group, 1996; Zilmer, 1992.*

The figures in parentheses in Table 3 are based on estimates from 1989. Since 1989, the number of accidents in which roller skaters were involved has increased significantly, for which reason the figures in parentheses can actually be between 5 and 15% higher.

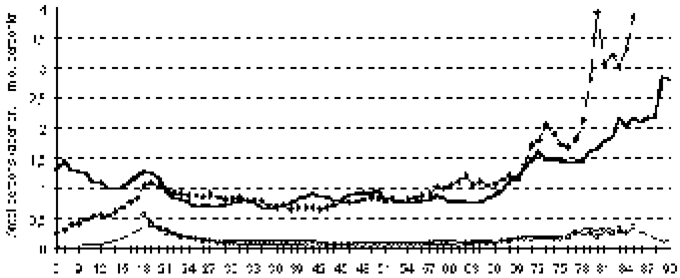
It can be seen from Table 3 that, in relation to car occupants, pedestrians are injured about 30 times more often per person kilometre and about 3 times more often per trip or person hour travelled. Cyclists are in even greater danger in traffic than pedestrians. In this context "to be injured" means to have visited a doctor or casualty ward. We must emphasise that the figures of Table 3 should be considered with caution, as the extent to which the Odense police record accidents involving casualties is not necessarily typical of the rest of the country. Trips of less than 300 metres are not included in Table 3. If trips of less than 300 metres are also considered, a walk is more than twice as risky as a trip by car.

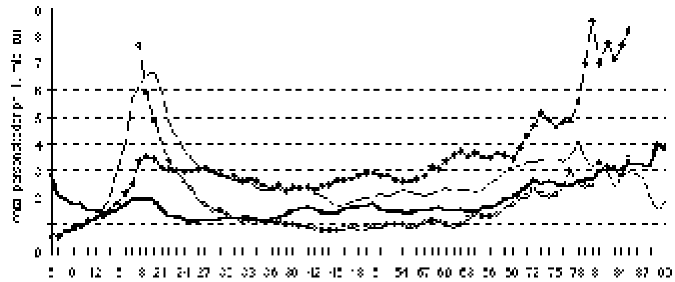
According to Table 2, the transfer of a moderate number of private car trips to trips on foot would probably not significantly affect the total number of police recorded casualties, all other things being equal. This is because the number of trips and person hours travelled would probably remain about the same. The transfer of private car trips to trips on foot would cause an overall increase in the number of casualties recorded by hospitals, as a consequence of the greater number of falls occurring among pedestrians. The transfer of a moderate number of private car trips to trips by bicycle would result in an overall increase in the number of casualties recorded by the police and by hospitals, as cyclists have a relatively high own risk, regardless of the measure of exposure used. The assessment of changes in traffic composition from the standpoint of road safety is theoretical; thus, no allowance has been made for the effects of transferring private car trips to cycling and walking, e.g., on the design of the road network, traffic patterns (which roads are used) and also road safety actions.

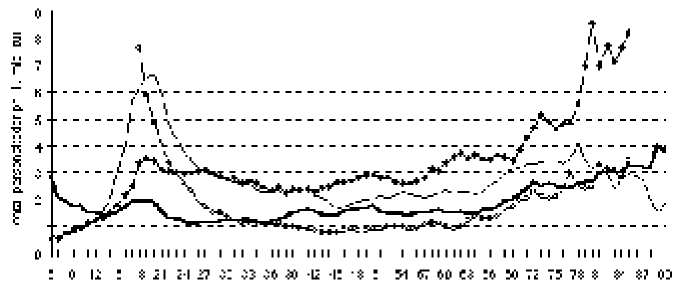
Figure 4 overleaf illustrates the own risk of pedestrians, cyclists, private car drivers and passengers. In the figure, own risk has been estimated from the standpoint of three measures of exposure, i.e., person kilometres, trips and person hours travelled. Furthermore, the figure also shows the differences according to age.

Regardless of the measure of exposure, the own risk of pedestrians increases from the age of 65. For instance, the casualty rate per walked kilometre for a 90-year-old pedestrian is about 3.5 times greater than that for a 65-year-old. The own risk for cyclists also increases from the age of 65. The risk assessment for elderly cyclists is somewhat uncertain, as the result of the combination of a relatively small number of interviews with the fact that only a modest proportion of the elderly cycle. The own risk for private car drivers increases from the age of 50 up to 77-78, from which age it remains fairly constant.

For all road users, the own risk for 16 to 24-year-old is higher than that of the 25 to 60-year-old. 30% of the walks undertaken by young people take place during the hours of darkness, whereas the corresponding figure for the middle-aged is only 20%. In darkness, the own risk for pedestrians is about 2.7 times higher than in daylight in urban areas and about 7.4 times higher in rural areas. These differences in travel behaviour, which have not been investigated for cyclists and car occupants, can therefore be of significance in explaining the high own risk for young people. The very high own risk for 18 to 22-year-old car occupants can be due to their lack of driving experience.







Of cyclists, the 6 to 13-year-old have the lowest own risk. This can be due to the fact that children cycle to a large extent on low trafficked roads or else they cycle in the company of adults. 6 to 13-year-old children also have the lowest own risk of all passengers in private cars. Between the sixth and eleventh year, the casualty rate per walked kilometre and trip drops steadily with increasing age.

The assessment on page 11 was that a modest transfer from car travel to walking would not greatly change the number of police recorded casualties, although it would increase the number of casualties recorded by hospitals as a result of more falls. The result of a transfer from car to walking for 6 to 13-year-old would not accord with this assessment since children as passengers in private cars are fairly safe, whereas children as pedestrians are exposed. A transfer from car to walking for 6 to 13-year-old would probably also increase the number of police recorded casualties. The assessment on page 10 applies in the case of other age groups.

2.4 Summary

The number of pedestrian casualties in Denmark has dropped by 26% during the past decade; for urban areas alone, there was a drop of 30%. The trend in casualties has been less favourable in the case of cyclists since the number cyclist casualties remains unchanged. Car occupants have experienced a more favourable casualty trend than pedestrians in urban areas, although there are no great differences in the entire country in the casualty trends for respectively car occupants and pedestrians.

The trend in person kilometrage indicates a rather different course of development. The own risk for private car occupants has dropped by about 43% during the period 1981 to 1993-1995, while the own risk for pedestrians has dropped by about 8% and the own risk for cyclists is unchanged. These figures are, however, somewhat uncertain.

On the basis of police recorded accidents, walking and cycling are about 7 to 8 times more hazardous per person kilometre than is travel by private car, whereas travel by private car is more hazardous per trip than walking. Cycling is twice as risky per person hour travelled than are walking and private car travel. According to hospital records a walk is safer than a car trip, although if pedestrians' single accidents are included, a walk is more than twice as dangerous as a car trip.

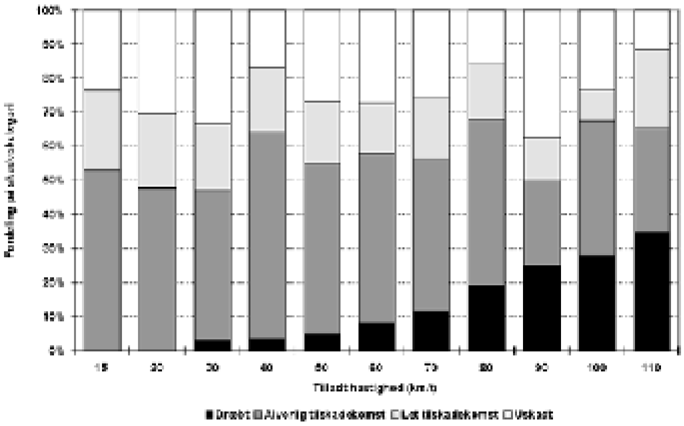
All other things being equal, the transfer of a modest number of car trips to trips on foot would not significantly change the overall number of police recorded casualties because the number of trips and person hours travelled would probably remain about the same. The transfer of car trips to trips on foot would increase the overall number of casualties recorded by hospitals as a result of the increase in the number of pedestrian falls. The result of a transfer from car to walking for 6 to 13-year-old would not accord with this assessment since children as passengers in private cars are fairly safe, whereas children as pedestrians are exposed. A transfer from car to walking for 6 to 13-year-old would probably also increase the number of police recorded casualties. The transfer of a moderate number of car trips to bicycle trips would result in an overall increase in the number of casualties recorded by the police and by hospitals, as cyclists have a relatively high own risk, regardless of the measure of exposure used. The assessment of changes to modal split from the standpoint of road safety is theoretical; thus, no allowance has been made for the effects of transferring car trips to cycle and walking, e.g., on the design of the road network, traffic patterns (which roads are used) and also road safety actions.

3. Key areas in road safety

The Danish Road Safety Commission's Strategic Plan 1995-2000 and the Government Road Safety Action Plan designate four key target areas for accident prevention measures: excessively high speed, drunken driving, cyclists and accidents at junctions. The reason for designating these key areas is that it makes the plan simple and clear, thus improving the basis for a broader debate, greater participation and for collaboration on the plan. Furthermore, the four key areas offer great potential for reducing the number of casualties, as five out of six such accidents are within the scope of action within the four key areas. This chapter includes some general reflections on speed, alcohol and road layout in relation to pedestrian safety.

3.1 Speed

Figure 5 shows a clear relationship between the severity of pedestrian casualties and the speed limit.



The proportion of pedestrians killed in accidents increases in step with the speed limit. Thus, there were no pedestrian fatalities on roads where the speed limit was 15 or 20 km/h during the period 1986-1995, whereas 35% of the pedestrians involved in accidents on motorways with a speed limit of 110 km/h were killed, see Figure 5. In other words, speed kills.

The proportion of pedestrians who receive slight and serious injuries in accidents drops in step with the speed limit, whereas there is no clear relationship between the speed limit and the proportion of pedestrians involved in accidents who receive no injuries, see Figure 5.

The severity of accidents tends to drop as the speed drops, and the number of fatal accidents drops more than the number of casualties when the average speed is reduced (Elvik, 1988).

Finch et al. (1994) have analysed 24 studies of changed speed limits and of intensified police enforcement and they have derived a relationship between average speeds and number of accidents. A change of 1.6 km/h is accompanied by a 5% change in the number of accidents, in the same direction (increasing or decreasing).

Another factor of significance to road safety is the scatter of the speeds of vehicles, as has been shown by Stark (1996). Stark plainly states that the average speed does not provide sufficient information for forecasting the occurrence of accidents. Stark finds that pedestrian safety is significantly linked to the scatter of the speeds of motor vehicles on road links but not at junctions.

In the following, six specific studies of the relationship between speed and accidents are reviewed.

In the city of Graz, Austria (pop. 240,000), the speed limit on local roads was reduced in 1992, from 50 km/h to 30 km/h. The average speed of motor vehicles dropped only slightly, whereas the number of very high speeds dropped dramatically. The proportion of drivers who exceeded 50 km/h dropped from 7% to 3%. Speeds were measured at 78 locations on the road network. The number of pedestrians involved in accidents dropped significantly by 17%, whereas the number of other road users involved in accidents dropped significantly by only 9% (Sammer and Wernsperger, 1995). This study indicates that a reduction in the scatter of motor vehicle speeds can lead to a significant reduction in the number of pedestrian accidents.

At the beginning of the 1980s, Switzerland tested a general reduction of the speed limit in urban areas, from 60 km/h to 50 km/h. Depending on the type of road, drops were measured in the average speeds of motor vehicles of between 0.5 and 5.2 km/h. The safety effect also differed widely for the individual modes of transport. The number of pedestrian casualties dropped significantly by 21%, whereas the change for other road users varied by between +11% and -19% (Engel and Thomsen, 1988).

Denmark introduced general speed limits for road traffic in 1974: 60 km/h in urban areas and 90 km/h in rural areas (110 km/h on motorways). Based on the results obtained from 24 measuring locations, the primary conclusion was that the average speed of motor vehicles dropped by 6 km/h and the scatter of speeds dropped by 3 km/h. The number of pedestrian casualties dropped significantly by 25%, whereas the number of casualties other than pedestrians dropped significantly by 21%. When these figures are corrected for the lower estimated traffic kilometrage, the drop in pedestrian casualties amounts to 21%, and to 14% for other casualties (Brodersen et al., 1975).

In 1985, the general speed limit in urban areas in Denmark was reduced from 60 km/h to 50 km/h. Depending on the type of road, changes of between -3.3% and +.4% were measured in the average speed of motor vehicles (based on measurements at 66 measuring locations). Changes in the number of casualties has been corrected by the application of a model which analyses the relationship between the number of accidents in urban and rural areas. No conclusions have been drawn on accident trends for the individual groups of road user. If all accidents are considered, the number of casualties dropped significantly by 9%, whereas the reduction in fatalities amounted to 24% (Engel and Thomsen, 1988).

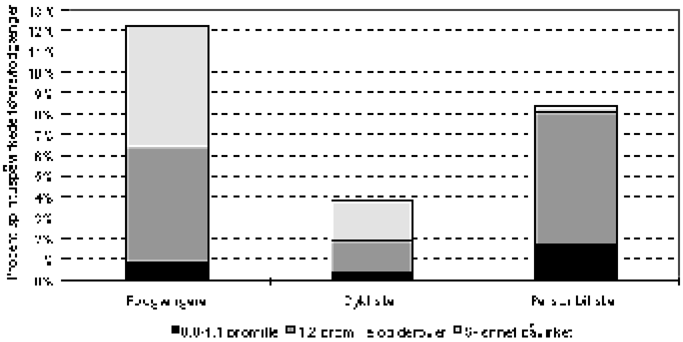
Since 1990, the state of Victoria, Australia, implemented a major programme of speed camera enforcement and random breath testing of blood-alcohol levels. The number of pedestrian fatalities and serious injuries dropped by 40% and 23%, respectively. If all groups of road user are considered together, the figures are 49% and 32%, respectively (Corben et al., 1996).

An English before-and-after accident survey of 20 mph (32 km/h) zones shows a significant drop of 63% in pedestrian casualties. If all injury accidents are considered, the drop was 61%. Safety effects should be seen in the context of a 15 km/h drop in the average speed and a 19% drop in car kilometrage. Speed reducing measures were used, 82% of which comprised bumps (Mackie and Webster, 1996).

The studies show that the average speed and the distribution of motor vehicle speeds have a great impact on pedestrian safety. In three of five studies reviewed, the safety effect for pedestrians was greater than for the other groups of road user, although one study found it to be less and another found it to be the same. While the average speed dropped by between 0.5 and 15 km/h, the number of pedestrian accidents and pedestrian casualties dropped by between 17 and 63%.

3.2 Alcohol

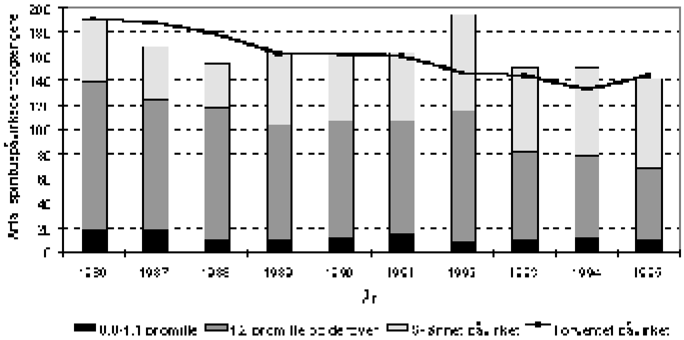
The relationship between drunken driving and traffic accidents is well-documented. Unfortunately only very limited information is available on the significance of the level blood-alcohol concentration to pedestrian risk.



Police tests and assessments of persons involved in accidents indicate that, in relation to motorists and cyclists, a greater proportion of pedestrians involved in accidents are intoxicated. Figure 6 shows that only 4% of the cyclists involved in injury accidents are intoxicated, whereas 8% of the motorists, and as much as 12% of the pedestrians, are intoxicated. 20% of pedestrian fatalities which occurred during the years 1993-1995 were intoxicated.

Figure 7 shows the trend in the number of intoxicated pedestrians involved in injury accidents for the period 1986-1995. There was a pronounced drop in the number of intoxicated motorists involved in accidents during the years 1989-91, whereas the number of intoxicated pedestrians involved in accidents remained the same. The trend in intoxicated pedestrians involved in accidents more or less followed the accident trend among sober pedestrians. The drop in the number of intoxicated motorists involved in accidents has been beneficial to pedestrian safety, since the number of casualties among sober pedestrians involved in accidents in which alcohol was a factor has dropped by between 30 and 35% during the period 1986-1995, i.e., by 5 to 10% more than among sober pedestrians involved in accidents in which alcohol was not a factor. 33 sober pedestrians were casualties in accidents with intoxicated drivers in 1995.

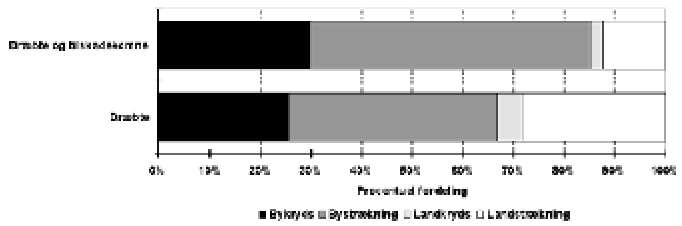
Figure 7 indicates that the measures applied so far against alcohol have not affected the trend in intoxicated pedestrians involved in injury accidents. This is because the trend in the number of intoxicated pedestrians involved in injury accidents follows the trend in the number of pedestrians involved in injury accidents without intoxicated drivers/pedestrians. It can be seen from Figure 7 that blood tests are carried out on a steadily diminishing proportion of intoxicated pedestrians.



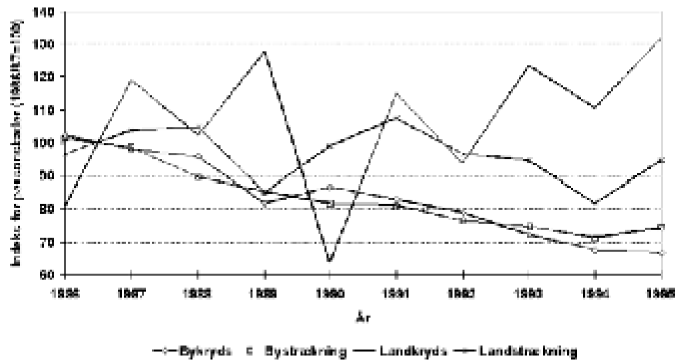
The Government Road Safety Action Plan includes a vigorous campaign especially aimed at young car drivers and motor cyclists, although it also presumes campaigns aimed at intoxicated pedestrians, cyclists and moped riders.

3.3 Accident locations

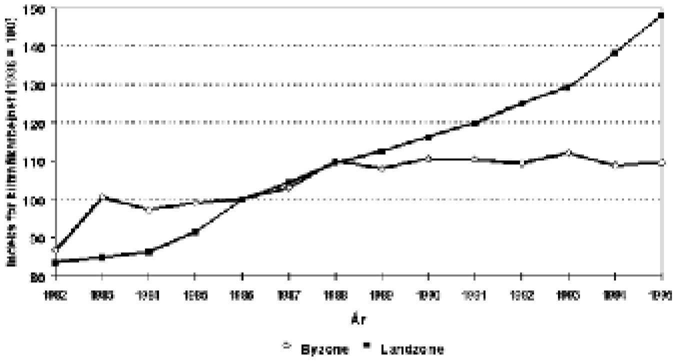
There are great differences in where the individual groups of road user get injured. For instance a 20% reduction in the accident rate at urban junctions would have different implications for the overall risk by modes of transport.



The greatest proportion of pedestrian fatalities and casualties is to be found on urban road links, see Figure 8. Corresponding estimates show that cyclists are primarily casualties at urban junctions, whereas the primary location for motorists is rural road links. A special action targeting junctions, which the Government Road Safety Action Plan prescribes, will improve the safety of cyclists in particular, if it can give the same accident reduction percentage at junctions for the individual groups of road users.



The trend in pedestrian casualties has been most favourable in urban areas, where the number of casualties has dropped by 30% during the period 1986-1995, see Figure 9. On the other hand, the number of pedestrian casualties in rural areas remains unchanged. There are no sharp differences in the pedestrian casualty trend between junctions and road links. In 1995, the number of pedestrian casualties was 972 in urban areas and 179 in rural areas.



The diverging trends in the car mileage in urban and rural areas (see Figure 10) can be a significant part of the explanation for the different trends in pedestrian casualties in urban and rural areas.

3.4 Summary

There is a clear relationship between severity of pedestrian casualties and the speed limit. The proportion of fatalities among pedestrians involved in accidents increases in step with the speed limit. In other words, speed kills.

The average speed and speed distribution of motor vehicles have great significance to pedestrian safety. In three of five speed reduction studies reviewed, the safety effect for pedestrians was greater than for the other groups of road user, although one study found it to be less and another found it to be the same. While the average speed dropped by between 0.5 and 15 km/h, the number of pedestrian accidents and pedestrian casualties dropped by between 17 and 63%.

Police tests and assessments of persons involved in accidents indicate that, in relation to car drivers and cyclists, a greater proportion of pedestrians involved in accidents are intoxicated. The measures applied so far against alcohol have not affected the trend in intoxicated pedestrians involved in injury accidents. The drop in intoxicated car drivers involved in accidents has been beneficial to pedestrian safety, since the number of casualties among sober pedestrians in accidents involving alcohol has dropped by between 30 and 35% during the period 1986-1995, i.e., by 5 to 10% more than among sober pedestrians involved in accidents in which alcohol was not a factor.

The greatest proportion of pedestrian fatalities and casualties is to be found on urban links. A special focus on junctions, which the Government Road Safety Action Plan prescribes, will improve the safety of cyclists in particular, if it can give the same accident reduction percentage at junctions for the individual groups of road user.

The trend in pedestrian casualties has been most favourable in urban areas, where the number of casualties has dropped by 30% during the period 1986-1995. On the other hand, the number of pedestrian casualties in rural zones remains unchanged.

4. Analyses of pedestrian accidents

This chapter focuses on pedestrian accidents. It is based on accidents recorded in Denmark by the police during the period 1986-1995. Various trends and estimates are a part of these analyses. This chapter clarifies the relationships between accident situations, accident locations and personal information on pedestrians.

4.1 Accident situations and locations

Table 4 overleaf provides an overview of accident situations, with number of injury accidents, pedestrian casualties and distribution over counterparts involved. Graphic explanations of accident situations are shown in Annex 2 and Figure 11 on page 25.

Accidents can be classified according to accident situations, so 49% can be considered as road link accidents, and 31% as junction accidents. On the basis of available information on the accident situation, the remaining 20% cannot be categorised solely as link or junction accidents. According to Table 4, at least 73% of injury accidents and fatal accidents occur when pedestrians are in the process of crossing carriageways, cycle paths or at junctions. Thus, the primary task from the standpoint of pedestrian safety must be to reduce the risk involved in crossing roads. Pedestrians walking along roads account for about 11% of pedestrian injury accidents.

Additional information on pedestrian accidents can be found in the following sections. We have attempted to uncover the circumstances surrounding the pedestrian accidents for which there has hitherto only been a limited body of knowledge. We have, for instance, focused on non-signalised roundabouts.

4.1.1 Accidents with reversing vehicles

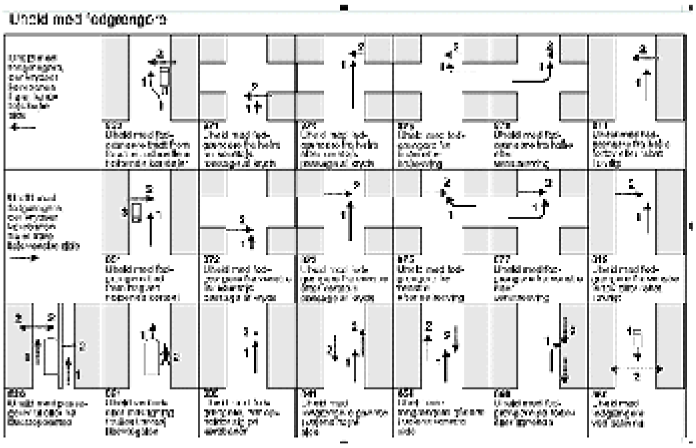
Reversing vehicles were involved in 5% of pedestrian injury accidents in 1993-1995. The number of pedestrian accidents with reversing vehicles has remained unchanged during the period 1986-1995. Accidents with reversing vehicles (accident situation 880) constitutes an increasing proportion of the total number of pedestrian accidents.

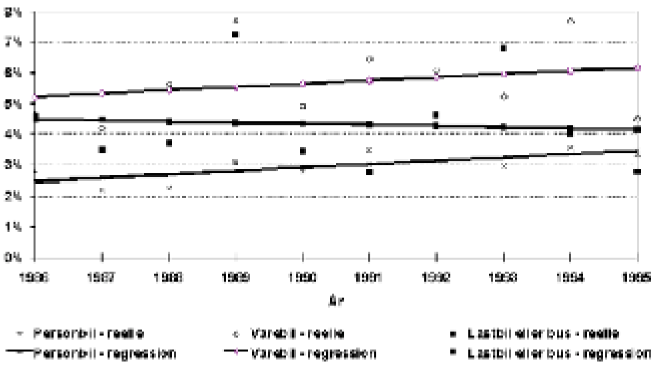
From 1 April 1985, it became permitted to install an audible warning device, which beeps during reversing manoeuvres, on all vehicles except for ordinary private cars. It is presumed that this audible warning device is able to reduce the number of accidents occurring between vehicles and cyclists/pedestrians. Since the device is not compulsory, it is conceivable that there will be an increasing safety effect while vehicles which lack the device are being replaced by vehicles equipped with it.

Accident situation	No. of injury accidents per year	Top 10 Hit list	No. of fatalities per year	Counterpart in injury accidents			
				Bicycles and mopeds	Private cars and mc	Vans	Trucks, buses
Accidents involving pedestrians crossing carriageways, cycle tracks or at junctions							
811	218	1	22	19%	68%	7%	6%
812	153	2	22	16%	70%	10%	4%
820	48	8	2	48%	36%	4%	12%
831	27		3	11%	75%	11%	2%
832	34		2	11%	76%	7%	5%
870	26		4	9%	69%	11%	11%
871	60	5	4	16%	60%	13%	11%
872	40	10	6	7%	81%	5%	7%
873	33		6	6%	77%	12%	5%
874	83	3	7	31%	51%	10%	7%
875	13		0	15%	57%	15%	10%
876	23		2	12%	52%	13%	23%
877	36		2	0%	73%	14%	13%
878	38		2	2%	69%	18%	12%
Accidents involving pedestrians walking along roads							
841	53	7	5	41%	44%	5%	7%
851	28		2	36%	49%	13%	2%
860	46	9	2	34%	50%	9%	7%
Other accident situations							
821	18		0	0%	15%	2%	83%
835	75	4	13	15%	60%	13%	9%
880	57	6	4	0%	65%	21%	12%

898	20		2	25%	50%	10%	10%
Other	16		3	5%	76%	13%	6%
Total	1144		116	18%	63%	10%	9%

***Table 4.** Pedestrian injury accidents by accident situations, with specification of number of fatalities and casualties, as well as of the distribution of counterparts. This does not total 100% in all cases, as tractors, horsemen and "not specified" are not included. NB: accident situation 870 represents accidents occurring at junctions, but for which no information is available on the locations of the elements. Accident situation 898 represents other pedestrian accidents. Source: Police recorded accidents 1993-1995.*





Accidents with reversing vehicles constitute an increasing proportion of injury accidents among cyclists and pedestrians in cases where the reversing vehicle is a private car or van, whereas the proportion for trucks and buses is dropping slowly, see Figure 12. The precise distribution of audible warning devices has not been estimated, although the immediate assumption is that these devices are installed today on trucks, rather than other types of vehicle. The favourable trend in accidents with reversing trucks and buses is noteworthy. This indicates audible warning devices have a beneficial safety effect.

If we assume that the distribution of the audible warning device among trucks and buses was 0% in 1986 and 100% in 1995, and if we let the trend in accidents between pedestrians/cyclists and reversing private cars describe the expected trend in accidents between pedestrians/cyclists and reversing trucks/buses, the safety effect of the device can be considered to reduce the number of reversing accidents by about 34%. Since the distribution of the device was not 100% in 1995, the safety effect is, in theory, greater, but as the exposure of pedestrians/cyclists to reversing vehicles is unknown, it is difficult to state a probable effect.

4.1.2 Accidents with cyclists as counterpart

A cyclist is the counterpart in rather more than 10% of all accidents involving pedestrian casualties. Accidents with cyclists as counterpart accounts for an annual 122 casualties among pedestrians. At Odense University Hospital, cyclists were counterparts in 28% of the collision accidents resulting in pedestrian casualties in 1995 (Accident Analysis Group, 1996). The extent to which the police record accidents is lower for pedestrians and cyclists (about 10%) than for other modes of transport (about 50%). The number of injury accidents between pedestrians and cyclists has remained unchanged, or dropping slowly, with 164 accidents in 1986 and 153 in 1995. Accidents between pedestrians and cyclists are not very serious, as only about 3 pedestrians are killed annually in accidents where cyclists are the counterpart. The following is a breakdown of the 153 injury accidents between pedestrians and cyclists in 1995:

- 14 accidents occurred on footways,
- 4 accidents occurred on pedestrian streets,
- 16 accidents occurred on separate paths,
- 20 accidents involved passengers boarding or alighting buses,
- 21 accidents occurred at signalised junctions; 6 pedestrians and 11 cyclists crossed against red lights,
- 11 accidents occurred at non-signalised junctions and 2, at entrances/exits,
- 3 accidents involved turning cyclists, the remainder were cycling straight ahead,
- 42% of the pedestrians were hit on their left-hand side, 21% on their right--hand side,
- 66% of the pedestrians were women.

The road safety problems arising between pedestrians and cyclists are concentrated around three circumstances: 1) cyclists cycling illicitly on footways, footpaths and pedestrian streets; 2) cyclists who fail to give way to passengers at bus stops and who cycle across red lights; 3) pedestrians who "forget" to look for cyclists approaching from the left or who fail to notice cyclists before crossing the cycle track/carriageway.

4.1.3 Accidents on or in vicinity of zebra crossings
Table 5 shows the proportions of pedestrian casualties that occur in accidents on or near zebra crossings. The total proportion of pedestrian casualties that occur on or near zebra crossings has dropped noticeably, from 32% in 1986, to 26% in 1995.

Location	On zebra crossing	Near zebra crossing	No zebra crossing	Total
Signalised junctions	85%	9%	6%	100%
Signalised links	75%	6%	19%	100%
Non-signalised junctions	26%	6%	68%	100%
Non-signalised links	6%	4%	90%	100%
Total	23%	5%	72%	100%

Table 5. *Casualties among crossing pedestrians by accident location and the presence and use of a zebra crossing. Source: Police recorded accidents 1993-95.*

If only pedestrian accidents occurring on and in the vicinity of zebra crossings are considered, it can be seen from Table 5 that a greater proportion of pedestrian casualties occur on the zebra crossing at signalised locations compared to non-signalised locations.

4.1.4 Non-signalised junctions
Vehicles travelling straight ahead are involved in about 85% of the fatal pedestrian accidents occurring at 3- and 4-armed non-signalised junctions. During the years 1993- 1995, 35 pedestrians were killed at 3-armed and 31 were killed at 4-armed non-signalised junctions. The severity of pedestrian accidents are about the same at 3- and 4-armed junctions. There are proportionally more accidents between left-turning vehicles and pedestrians at 4-armed junctions than at 3-armed junctions. The trend in the number of pedestrian accidents at non-signalised junctions has followed the general trend.

4.1.5 Signalised junctions
Pedestrian accidents at signalised junctions can be classified into three groups. Accidents in which all involved parties had a green light occurred in 42% of pedestrian injury accidents at signalised junctions, jay-walking occurred in 43% and red driving in 18% of pedestrian injury accidents during the period 1993-1995.

5 pedestrians were killed at 3-armed, signalised junctions in 1993-1995. They were all crossing against red lights. Similarly, 35 pedestrians were killed at 4-armed junctions. Of these 35, 19 were crossing against red lights and 16, against green lights. 10 of the latter were killed by left-turning vehicles and 5 by right-turning vehicles. The last fatality was a 75-year-old woman who did not manage to cross a 4-lane road before the intersecting traffic received a green light, when an articulated truck drove out.

Many circumstances affect the extent of jay-walking. Based on a survey of jay-walking at 38 crossings in 15 Swedish towns, Gårder (1982) developed a model for estimating the proportion of jay-walking as a percentage of the number of pedestrians arriving at a crossing during the red phase. There is a close relationship between the proportions given by the model and the true proportions. The circumstances included in the model, which thus influenced the extent of jay-walking were, e.g., town size, road width, presence of central islands, quantities of pedestrian and vehicular traffic and the presence of a push-button for pedestrians, if this was necessary for pedestrians to obtain a green light. The risk involved in crossing against a red light is between 5 and 10 times greater than crossing on a green light. Gårder's model can probably not be applied to Danish conditions without modification, as it is not illegal to cross against a red light in Sweden, whereas it is illegal in Denmark.

Between midnight and 6.00 a.m, about 75% of all pedestrian casualties at signalised junctions crossed against red lights, whereas only about 35% of the victims did so between 6.00 a.m. and 6.00 p.m., see Figure 13. This indicates that the following circumstances possibly influence the extent of jay-walking: quantities of pedestrian and vehicular traffic, number of intoxicated pedestrians, number of young pedestrians and the signal cycle time.

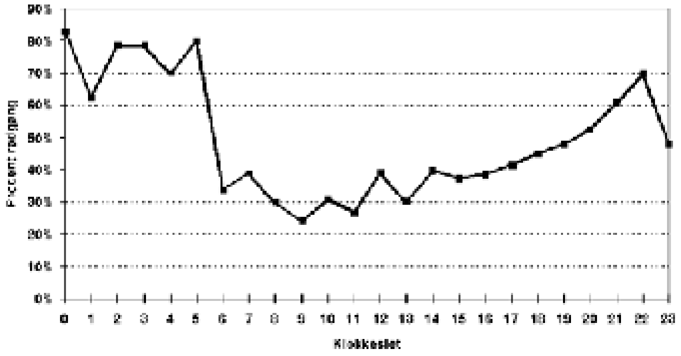
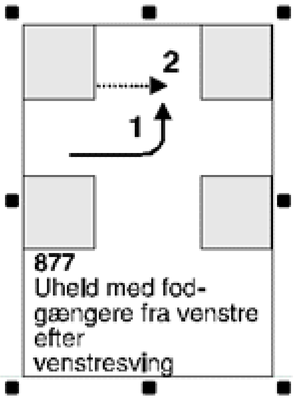


Figure 13. *Figure 13 Percentage jay-walking among pedestrian casualties at signalised junctions by the hour of the day. Source: Police recorded accidents 1986-95.*

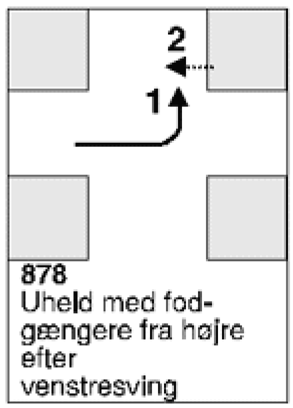
Many traffic signals in Finland, Norway and Sweden are routinely set to flashing amber at night. A survey from Stockholm showed an unchanged number of pedestrian accidents as a result of this type of traffic-signal control (i.e., flashing amber or deactivated signals), whereas the number of car accidents increased (Ekman and Kronborg, 1995). Norwegian and American surveys show that flashing amber increases the overall accident figures for all types of traffic (TØI, 1989).



Ekman and Kronborg (1995) write that advanced control strategies, such as separate turning phases and bus priority, can be the cause of an increased risk to pedestrians, in comparison to simple control with two phases. This is due to the fact that pedestrians often cross against red lights. The risk is about 10 times higher for the jay-walker who believes that there is no risk in crossing the road when potential counterparts are present than for the jay-walker who is wary of potential counterparts.

In 1993-1995, 56% of pedestrian casualties at signalised junctions in the Municipality of Copenhagen were crossing against red lights, whereas only 35% of the pedestrian fatalities and casualties did so in other municipalities. The reasons for this difference are not known.

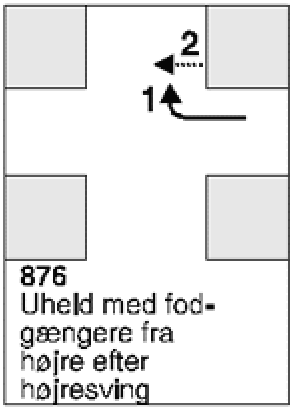
Accidents with turning vehicles are one of the most significant problems for pedestrians at signalised junctions. The total number of accidents with left-turning vehicles at all types of junction (accident situation 877 and 878) is twice the number of accidents with right-turning vehicles (875 and 876). The risk of being hit by a left-turning vehicle is about 2.3 times greater than that of a right-turning vehicle at 4-armed, signalised junctions, and about 3.5 times greater at 3-armed signalised junctions.

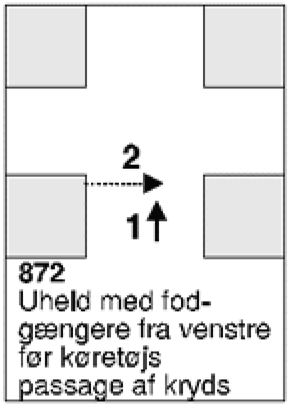


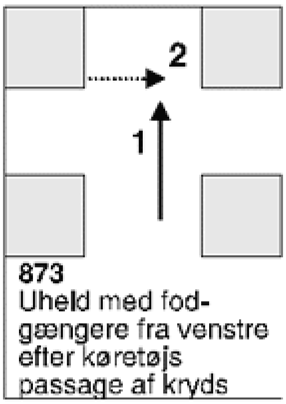
54% of the type 877 accidents occur in darkness, whereas only 28% of type 878 accidents occur in darkness. Hypothesis: when pedestrians become less visible to potential counterparts, which occurs in darkness, their risk must become more dependent on their orientation capability. Part of the explanation can be that a pedestrian's field of vision in the type 877 situation is not directed towards left-turning vehicles to anything like the same extent as that of a pedestrian in the type 878 situation. Better illumination of signalised junctions can be expected to reduce the frequency of type 877 accidents more than that of type 878 accidents.

According to Table 4, trucks and buses are over-represented in the type 876 situation. This applies only at signalised junctions, where a third of the counterparts are trucks or buses. This accident situation has several parallels with the problems surrounding the type 312 accidents of cyclists. Truck and bus drivers are sometimes unable to see cyclists because of blind angles. With a view to reducing the effect of blind angles, trucks have been fitted with supplementary side mirrors and the vehicle stop line is in many places recessed by about 5 m relative to the cyclists stop line at signalised junctions with extended cycle tracks or lanes. Assessments of these measures indicate that supplementary side mirrors have no effect on the occurrence of type 312 accidents (Behrensdorff and Hansen, 1994), whereas recessed stop lines have a favourable effect on such accidents at the beginning of the green phase (Danish Road Directorate, 1994).

Due to the parallels to accident situation 876 there is good reason for believing that recessed stop lines also have a beneficial effect for pedestrians. Recessing stop lines may also reduce the number of type 872 and type 873 accidents, since such stop lines serve to extend the intergreen period, to make pedestrians in accident situation 872 more visible to motorists and they offer space for avoidance manoeuvres. 80% of pedestrian casualties in types 872 and 873 accidents cross against red lights. 71% of types 872 and 873 accidents at signalised junctions occur on roads with 4 lanes or more, whereas only 49% of other accidents at signalised junctions occur on roads with 4 lanes or more.

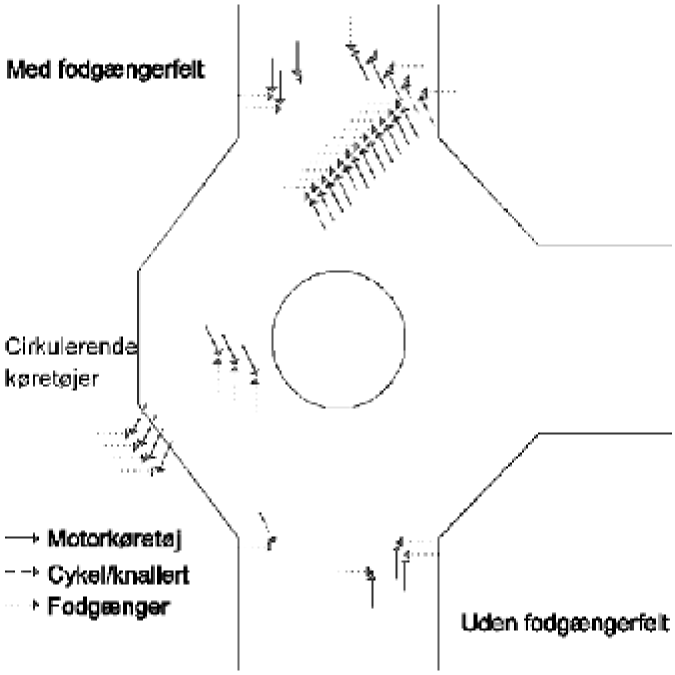






4.1.6 Roundabouts
38 accidents occurred at roundabouts during the period 1986-1995 in Denmark. Of these, 31 occurred at 28 non-signalised roundabouts, of which 20 were injury accidents. 7 accidents occurred at a single, signalised roundabout. The 31 accidents at non-signalised roundabouts are described in the following. 30 of the 31 accidents occurred in urban areas and one accident in a rural area. There is nothing unusual about the accidents regarding the distributions of the sexes or ages of the pedestrians, nor about the prevailing weather conditions, road conditions or time of day.

7 accidents occurred on the roundabouts themselves. In 4 accidents, a moped rider and three private motorists lost control and ran up onto the footway, where they hit pedestrians. The other 3 accidents included one at road works and one secondary accident. The pedestrians involved in these three accidents were on the carriageway and were struck by circulating vehicles. 3 pedestrians received serious injuries in the 7 accidents.



4 accidents occurred in arms of roundabouts without zebra crossings. 2 accidents occurred between entering cars and pedestrians approaching from the right-hand sides of the vehicles. One accident occurred between an exiting ambulance and a pedestrian approaching from the left-hand side of the vehicle. A total of 3 pedestrians were seriously injured in these accidents.

20 accidents occurred in arms of roundabouts with zebra crossings. The pedestrian did not use the zebra crossing in only one accident. 2 accidents occurred between entering cars and pedestrians who approached from the right-hand side of the vehicles. In one accident, the parties involved were an entering car and a pedestrian who approached from the left-hand side of the vehicle. 4 accidents occurred between pedestrians who approached from the right-hand sides of vehicles leaving the roundabout, i.e., 2 cycles, a car and a coach. The parties involved in 12 accidents were exiting vehicles and pedestrians who approached from the left-hand sides of the vehicles. 9 cars, one truck and 2 cycles were involved in the 12 accidents. The last accident occurred between an exiting car and a pedestrian who was on the carriageway. The pedestrians received 3 slight and 11 serious injuries in the 20 accidents.

Overall, the accidents were distributed as 7 with circulating vehicles, 18 with exiting vehicles and 6 with entering vehicles. The pedestrians involved in 17 accidents were approaching the circulating traffic. In 6 accidents, the pedestrians involved were moving in the same direction as the circulating vehicles. The distribution of the accidents gives rise to three hypotheses:

1) The drivers of entering vehicles look more to the left to find a gap in the traffic and, to some extent, "forget" that pedestrians can approach from the right-hand side of the vehicle.

2) The drivers of exiting vehicles look more for pedestrians approaching from the right-hand side of the vehicle and at the exit from which they will leave. This means that these drivers can to some extent "forget" to watch for pedestrians approaching from the left-hand side of the vehicle.

3) The construction of zebra crossings reduces the number of accidents occurring between entering vehicles and pedestrians and/or increases the number of accidents between exiting vehicles and pedestrians.

Together, Hypotheses 1 and 2 underline the fact that the drivers of vehicles expect one-way traffic at roundabouts.

38 roundabouts were constructed during the period 1970-1975 in London, and they replaced non-signalised junctions. A before-and-after injury accident study shows a 52% drop in the number of pedestrian accidents that occurs within 20 m of the junction and a significant drop of 46% in the number of pedestrian accidents that occurs within 50 m of the junction. The number of seriously injured and killed pedestrians (less than 50 m from junction) dropped by 70%. 20 of the 38 roundabouts were mini-roundabouts, with central-island diameters of between 1 and 4 m. The safety effect of mini--round-abouts was about the same, since drops of 50% (less than 20 m from junction) and 38% (less than 50 m from junction) in the number of pedestrian accidents was noted. (Lalani, 1975)

A before-and-after accident study of the construction of 201 roundabouts in Holland shows a significant drop of 47% in the number of accidents and of 71% in the number of casualties. The number of pedestrian casualties dropped by 89%. The Dutch write that the safety improvement is partly due to the complete avoidance of certain conflicts and to the fact that pedestrian crossings are made less complicated, although the safety improvement is especially due to a drop in the speed of the motor vehicles. (Schoon and Van Minnen, 1994)

Studies of motorists' practices concerning pedestrian rights of way at zebra crossings, conducted at roundabouts in Norway, show that 58% of motorists stop as required by law. The proportion is smallest for exiting motorists (49%) and greatest for entering motorists (67%). In the opinion of the Norwegians, the results underline the importance of clearly marking zebra crossings for exiting motorists and the advantages of moving zebra crossings away from roundabouts by about 10 to 12 m. (Johannessen, 1985)

4.2 Differences in geography and urban structures

It became quite apparent in Section 3.3 that the trends in pedestrian casualties in urban and rural areas differed widely. This difference can be explained to a great extent by the different trends in car kilometrage. This section describes differences in the trend in casualties and risk, in terms of geography and urban structure.

	Daylight	Twilight and darkness	Crossing	Walking along roads	Total
Urban areas	0.74	1.97	0.79	0.11	1.03
Rural areas	0.28	2.08	0.26	0.18	0.59

Table 6 *Pedestrian casualties per million walked km (own risk) for pedestrians aged 16 to 74 years, distributed over urban and rural areas, light conditions and also accident situations with crossing pedestrians and pedestrians walking along roads, respectively. Source: Police recorded accidents 1993-95; National travel survey 1993-95.*

It can be seen from Table 6 that the number of pedestrian casualties per walked km is about 40% lower in rural areas. This is probably due to the fact that pedestrians cross more roads per walked km in urban areas, as the risk to crossing pedestrians per walked km is about three times higher in such urban areas than in rural areas. Walking one km in urban areas is about 2.7 times more dangerous in twilight or darkness than in daylight, whereas it is about 7.4 times more dangerous in rural areas.

Municipality	Crossing pedestrians		Pedestrians misc.
	On links	At junctions	
Copenhagen and Frederiksberg	34%	42%	24%

Suburbs close to Copenhagen	40%	33%	27%
Aalborg, Odense and Århus	36%	39%	25%
Municipalities with 50,000-99,999 inhabitants	39%	30%	31%
Municipalities with 25,000-49,999 inhabitants	38%	33%	29%
Municipalities with 0-25,000 inhabitants	39%	17%	44%

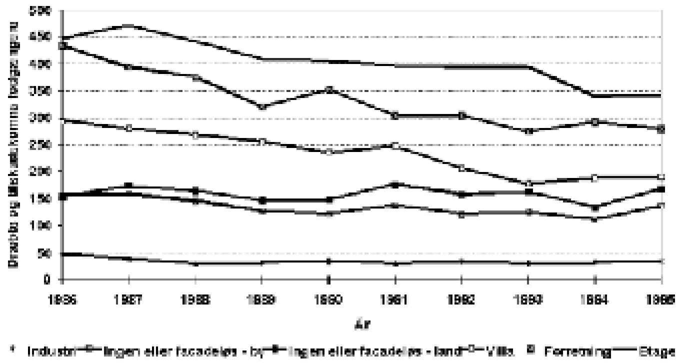
Tabel 7. *Pedestrian casualties by accident situations and urbanisation. Source: Police recorded accidents 1993-95.*

Together, Tables 6, 7 and 8 underline the fact that a high population density leads to a high own risk per person km for pedestrians. Table 7 shows that the higher the population density, the greater share of pedestrian accidents at junctions.

Municipality	Pedestrian casualties per million walked km	Walked km per person per day
Copenhagen and Frederiksberg	1.3	0.9
Suburbs close to Copenhagen	0.8	0.7
Aalborg, Odense and Århus	1.0	0.7
Municipalities with 50,000-99,999 inhabitants	0.7	0.6
Municipalities with 25,000-49,999 inhabitants	0.8	0.6
Municipalities with 0-25,000 inhabitants	0.8	0.4

Table 8. *Pedestrian casualties per million walked km (own risk) for pedestrians aged 16 to 74 years and number of walked km per person per day by urbanisation. Source: Police recorded accidents 1993-95; National travel survey 1993-95.*

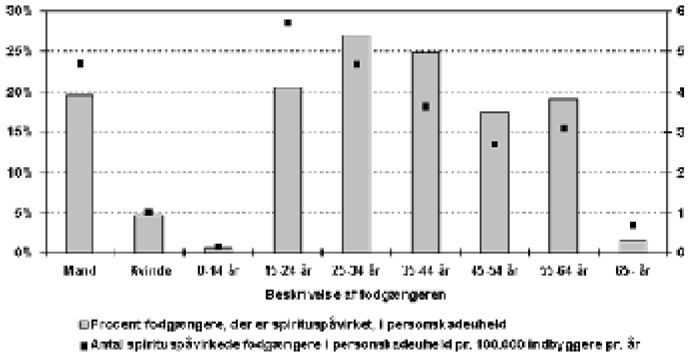
The high own risk and number of walked km per person per day in major urban areas indicates a concentration of pedestrian accidents in these municipalities, see Table 8. Thus, 39% of Danish pedestrian casualties occurred in Copenhagen, Frederiksberg, Aalborg, Odense and Århus, although only 22% of the Danish population dwells in these cities. This means that pedestrian accidents are, to some extent, a city problem.



It is not merely in rural areas that the number of pedestrian casualties has remained unchanged during the period 1986-1995. The number of casualties on industrial roads and roads without frontage in urban areas also remains unchanged. In fact, it is only on roads with detached housing and multi-storey and shopping streets that the number of pedestrian casualties has dropped. The drop on such roads is about 30%. However, a considerable proportion of pedestrian casualties, i.e., 72%, still occurred on these roads during the period 1993-1995.

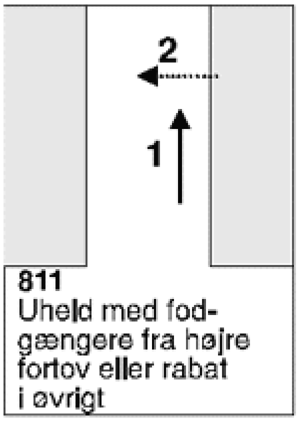
4.3 Accidents involving intoxicated pedestrians
Injury accidents involving intoxicated pedestrians ($ 0.8‰ blood-alcohol concentration or considered intoxicated) during the period 1993-1995 are described below.

Intoxicated pedestrians receive more serious injuries than sober pedestrians. Intoxicated pedestrians constitute 20% of pedestrian fatalities but only 12% of pedestrian casualties. Part of the explanation for this is that pedestrian accidents occurring during the hours of darkness (regardless of whether alcohol is involved) are more serious than accidents occurring in daylight. 77% of injury accidents with intoxicated pedestrians occur in darkness. The fact that the intoxicated pedestrians involved in injury accidents are mainly males aged between 15 and 64 is not surprising, see Figure 16.



The proportions of intoxicated pedestrians involved in injury accidents are 15.8% in rural areas and 11.6% in urban areas. The reason for this difference is that the accident frequency is relatively more dependent on the prevailing light conditions in rural areas than in towns (see Section 4.2) and not, apparently, because pedestrians are more frequently intoxicated in rural areas. There are no major regional differences in the proportion of intoxicated pedestrians involved in injury accidents.

When allowance is made for differences in the distribution of accidents in daylight, twilight and darkness, two accident situations are found to be over-represented in injury accidents with intoxicated pedestrians, in relation to accidents with sober pedestrians. These are accident situations 811 (over-represented by 42%) and 835 (over-represented by 114%). They are shown in the left-hand margin. This indicates that intoxicated pedestrians are less watchful for traffic approaching from the left before leaving the footway than are sober pedestrians and that intoxicated pedestrians have less respect for vehicles and stand more often on the carriageway.



If the accident situations involving crossing pedestrians are grouped into pedestrians crossing from the right-hand side of a vehicle (accident situation 811, 832, 871, 874, 876 and 878) and from the left-hand side of a vehicle (accident situation 812, 831, 872, 873, 875 and 877), we obtain a non-significant over-representation of 13% for accidents with pedestrians crossing from the right-hand side of a vehicle, and a non-signifi-cant under-representation of 12% from the left-hand side. Altogether, there is no deviation in the proportions of accidents involving crossing pedestrians who are intoxicated or who are sober.

4.4 Conditions of light and illumination
The distribution of pedestrian accidents by light conditions (daylight, twilight and darkness) has not changed during the period 1986-1995. Pedestrians are relatively frequently involved in accidents in darkness. 33% of pedestrian casualties occurred in darkness during the period 1993-1995. Accidents occurring in darkness are more serious than accidents in daylight. 49% of pedestrian fatalities occurred in darkness.

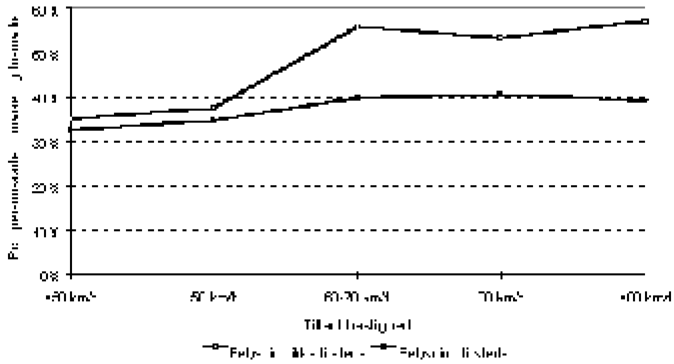
	Road lighting		No road lighting	
Light conditions	Daylight	Darkness*	Daylight	Darkness*
Pedestrian crossing from right-hand side of vehicle	30.3%	12.7%	13.0%	5.6%
Pedestrian crossing from left-hand side of vehicle	14.2%	13.7%	9.8%	9.8%
Pedestrian walking along road on footway or alike	2.9%	1.6%	0.8%	1.0%
Ped. walking along road without footway or alike	1.8%	1.5%	5.6%	1.,2%
Other accident situations	15.2%	6.1%	19.6%	1.,8%
Sub-total	64.4%	35.6%	48.7%	51.3%
Total	100%		100%	

Table 9. *Pedestrian casualties by conditions of light and illumination and also accident situation. Darkness* = darkness and twilight. Source: Police recorded accidents 1993-95.*

Table 9 immediately reveals that the presence of road lighting is significant to the distribution of accidents according to light conditions. This applies to pedestrians walking along roads and to pedestrians in “other accident situations”. On the other hand, it appears that road lighting has no impact on the distribution over light conditions of accidents involving crossing pedestrians.

The above classification into "Road lighting" and "No road lighting" is strongly correlated with other parameters. Thus, 96% of the pedestrians became casualties in urban areas, where road lighting was present, whereas road lighting was only present in 23% of accidents in rural areas. The permitted speed, density of pedestrian facilities and junctions are also very different in urban and rural areas.

Table 9 shows that, on roads with footways or alike, relatively fewer pedestrians walking along roads become casualties in darkness than on roads lacking such facilities. The relationships between the speed limit, conditions of illumination and the distribution of pedestrian casualties over light conditions are shown in Figure 17.



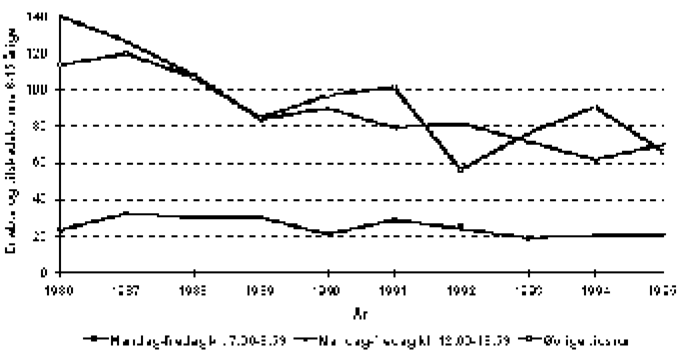
On roads with a speed limit of up to 50 km/h, there is only a difference of 3% in the distribution of pedestrian casualties over light conditions, for the presence/absence of road lighting, whereas the difference in about 15% on roads where the speed limit exceeds 50 km/h, see Figure 17.

By assuming that road lighting does not change the number of pedestrian accidents occurring in daylight, but only reduces the number of pedestrian accidents occurring in darkness, so that the distribution of accidents over light conditions changes as shown in Figure 17, the effect of installing road lighting can be estimated to give a reduction of about 45% of the pedestrian casualties occurring in darkness on roads where the speed limit exceeds 50 km/h. This effect is debatable, since a larger proportion of accidents occurs at zebra crossings, on footways and at junctions when road lighting is present than when road lighting is absent.

Section 5.14 reviews studies in which the installation of road lighting has resulted in a drop of 35 to 43% in the number of pedestrian accidents occurring in darkness.

4.5 School roads

It must be assumed that the morning and afternoon hours are the periods in which traffic-calming measures implemented on school roads have the greatest significance for the road safety of children. The casualty trend for 6-15-year-old is shown in Figure 18. The application of regression reveals that the drops in the number of casualties for this group of pedestrians are 34% and 52%, during weekday morning and afternoon hours, respectively, and 41% at other times. During the period 1986-1995, the number of 6-15-year-old in Denmark dropped by 20%. The number of 6-15-year-old fatalities has not changed over the period.



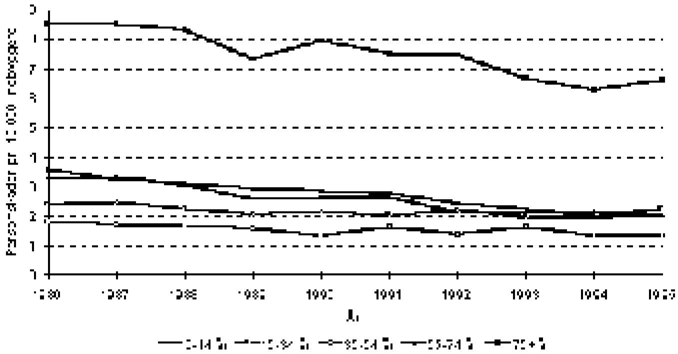
The number of 6-15-year-old pedestrian casualties per school child dropped by about 25% during the period 1986-1995, least when they are going to school and most when they leave the school. The differences in the casualty trend between the different times of day can be due to changes in children's travel behaviour.

A report on school roads from the city of Odense shows a drop of 82% in the number of casualties recorded by the casualty ward, after the implementation of traffic-calming measures on 12 roads during the years 1981-1986 (Andersen and Engel, 1994). The report contains no specific assessment of accidents in which children are involved.

A survey of the effect of school traffic patrols and of flashing traffic signals for school traffic patrols showed that the presence of school patrols in action reduced the average speed of cars significantly by about 3 km/h, whereas the presence of flashing traffic signals and patrols reduced the average speed of cars significantly by 8 km/h (Kjærgaard and Lahrmann, 1981).

4.6 Age differences

A high risk as a pedestrian is characteristic of small children aged between five to eight years and the elderly aged over 75 years. This section is mainly devoted to these two age groups.



"Health risk" is defined as the number of casualties per inhabitant. Figure 19 shows the health-risk trend by age groups. Throughout the entire period, the health risk was lowest for 35-54-year-old and highest for age group "75 and above". The health risks of the other three age groups are converging.

Age group	Walked km per day 1981	Walked km per day 1993-95	Casualties 1981	Casualties per year 1993-95	Change in wal-ked km	Change in casualties	Change in own risk
16-24 years	770,000	430,000	237	164	- 44%	- 31%	+ 24%
25-34 years	750,000	470,000	166	128	- 37%	- 23%	+ 23%
35-44 years	570,000	370,000	114	105	- 36%	- 8%	+ 42%
45-54 years	530,000	340,000	116	109	- 35%	- 6%	+ 46%
55-64 years	600,000	280,000	157	80	- 54%	- 49%	+ 9%
65-74 years	630,000	260,000	208	117	- 59%	- 44%	+ 36%
75+ years	380,000	380,000	278	237	- 0%	- 15%	- 15%
16+ years	4,200,000	2,500,000	1.276	940	- 40%	- 26%	+ 23%

Table 10. *Walked km and pedestrian casualties 1981 and 1993-95 by age groups. Trips of less than 300 metres are not included for 1993-95 Source: Police recorded accidents 1993-95; Danish Bureau of Statistics, 1982a and 1982b; National travel survey 1993-95; National travel survey of the elderly 1993-94.*

National travel surveys dating from 1981 and 1993-1995 have been used to compare the trends in the number of casualties and walked km by age groups, see Table 10. Trips of less than 300 metres are included in the 1981 survey, but not in that of 1993-1995, see also page 9 for more information on this. If trips of less than 300 metres are included for 1993-1995, the own risk actually dropped by 8% for persons aged 16 and above.

Table 10 shows a relatively clear relationship between the trends for casualties and for walked km. Age groups which exhibit a large percentage drop in walked km also exhibit a correspondingly large drop in casualties.

4.6.1 Children aged 5 to 8 years

Not surprisingly, Section 3.3 showed a higher own risk for small children than for large children and adults. Norway is reducing the obligatory school starting age from seven years to six during 1997. In connection with this, Midtland (1995) has conducted a study of the literature and an accident survey on small children as pedestrians.

Research and theory indicate two main problems with children as pedestrians. The one problem is their specific and egocentric thinking, which prevents them from taking points of view other than their immediate one, i.e., of understanding the situations of others. Another significant problem is their lack of ability to control themselves and to maintain their concentration. If a small child's attention is drawn to something on the other side of the road, the child will immediately cross it. However, their resistance to disturbing factors increases as they grow older, and from the age of eight years, most children will remain at the kerb. When children are distracted while performing a certain manoeuvre in traffic, their attention is drawn from that manoeuvre to whatever distracts them, while they continue to carry out the locomotory part of the manoeuvre. This means, for instance, that smaller children are not good at avoidance manoeuvres (Midtland, 1995).

Table 11 shows that most of the children involved in accidents are injured when they cross the road links, especially links with parked vehicles.

Midtland (1995) writes that small children are mainly involved in accidents occurring on road links that lack zebra crossings. This circumstance can be found in Danish pedestrian accidents, although a more detailed analysis of Danish accidents reveals that this is solely due to children's special problems with parked vehicles.

Accident situation/pedestrian’s manoeuvre	5-8 years	25-64 years	75+ years
Crossing on road links	44%	29%	33%
Crossing on road links with parked vehicles	18%	4%	3%
Crossing at junctions	23%	32%	38%
Bus passengers approaching or leaving bus stops	7%	4%	6%
Boarding or alighting vehicles	0%	1%	3%
Walking along roads on road links	4%	13%	6%
Standing on carriageway	2%	9%	2%
Accidents with reversing vehicles	1%	4%	8%
Other accident situations	2%	6%	2%
Total	100%	100%	100%
Number of casualties	866	4,507	2,644

Table 11 *Pedestrian casualties by accident situations and selected age groups. Source: Police recorded accidents 1986-95.*

The ability to carry out a thorough visual search in the traffic environment, to keep information active in their short-term memories and continuously to co-ordinate information does not improve significantly before the age of seven years, at which time it improves rapidly. These abilities are essential for assessing speed and distance, which are vital, e.g., when crossing a road (Midtland, 1995).

Small children are injured more often than other age groups on roads with detached housing and less often, on shopping streets. 67% of injured small children are boys, but boys constitute only 58% of the 0-4 year-old and only 55% of the 9-14 year-old pedestrian casualties. Of the small children involved in accidents, 16% were injured in twilight or darkness, against an average of 38% for the other age groups.

4.6.2 The elderly aged 75 years and over
Section 2.3 shows that the elderly aged 75 years and over had the highest own risk of all age groups. Part of the reason

for this is progressive weakening of the body. During 1993-1995, the age group 75 years and over constituted 40% of pedestrian fatalities, 21% of serious injuries, 13% of slight injuries and only 6% of the uninjured pedestrians. The elderly are more vulnerable than younger people. The proportion that constitutes unharmed pedestrians drops steadily through life, whereas the proportion of fatalities increases steadily.

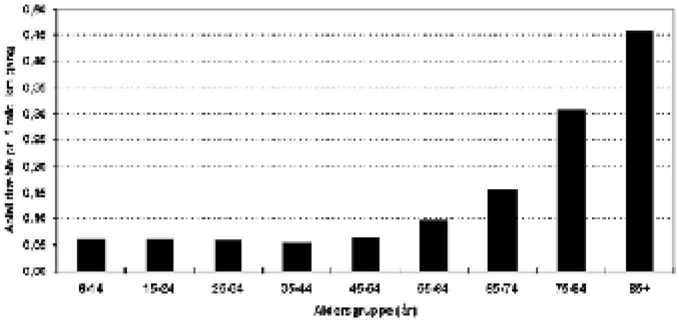


Figure 20 shows that the risk of being killed per walked km for pedestrians aged 85 years and over is about 8 times higher than that of 6-54-year-old pedestrians. A pedestrian is killed for every 10 million walked km.

Evans (1991) established two relationships for determining the probability of being killed in a given collision, one for males and one for females. These relationships were found by analysing American fatalities with a total of 80,000 victims. Only vehicles containing at least two people, and at least one fatality, were included in the analysis. Allowance was made for the use of safety belts and for the positions of the victims in cars or on motor cycles. Evans found that the probability of being killed in a given accident increased by 2.31% per year lived after the 20th year, for males, and 1.97% per year lived, for females. This means that the probability that an 80-year-old male will be killed in a given accident is four times greater than that of a 20-year-old male.

The differences in the mortality risk are smaller if correction is made for the natural weakening of the body that occurs with increasing age, as shown by Evans (1991). With this correction, the elderly over 74 years are still the most exposed age group.

There is still some doubt over the reasons for the higher own risk of the elderly as pedestrians. This is due to the fact that there is several possible explanations other than vulnerability, such as:

- Diminished spatial and depth perception, which makes it more difficult for the elderly to assess speed and distance. Only minor changes in depth perception occur up to the age of 40 years; a critical change occurs between 40 and 50 and depth perception diminishes rapidly up to the age of 75 years (Corso, 1982). This impairment of spatial and depth perception is probably due to changes in certain nerve cells in the cerebral cortex and is, therefore, often associated with senile dementia and other brain diseases.
- Diminished capacity for adapting to darkness, which is often designated night-blind-ness and which can be related to dazzling. These sight problems increase steadily from the age of about 25 to 30 years (Corso, 1982). Night-blindness cannot normally be improved through the use of spectacles or contact lenses.
- Diminished static and dynamic vision, which makes it more difficult for the elderly to distinguish detail. These problems can normally be mitigated through the use of spectacles or contact lenses. Static vision is at its best at an age of between 15 and 20 years, after which it decreases steadily; it can be improved by enhancing the contrast between the surroundings and the object, by increasing the amount of light, although it steadily deteriorates, despite enhanced contrast, after the age of 60 (Corso, 1982).
- Diminished hearing, which makes it more difficult for the elderly to hear approaching vehicles and the beepers of reversing vehicles. This impairment begins from the age of about 25 to 30 years and is most pronounced at high frequencies (Corso, 1982).
- The elderly walk more slowly and have greater difficulty in performing avoidance manoeuvres.
- Increasing indecision.
- Lack of driving experience.

These explanations are supported by a number of behaviour studies, experimental tests and medical examinations. Relatively few investigations have been conducted which directly relate the physiological and psychological impairments, etc., to accidents.

Behaviour studies conducted in the USA show that people of over 65 years old walk about 20% slower than younger people, regardless of whether this is measured at the median or some other percentile. People of over 65 walk at a median speed of 1.20 m/s, whereas younger people walk at 1.46 m/s. Pedestrians' reaction times at signalised junctions were measured in the same study. "Reaction time" denotes the time from when a pedestrian receives a green light until he or she takes the first step onto the carriageway. It took the elderly about 20% longer to start crossing the road - a median reaction time of 2.49 seconds, in contrast to the 1.95 seconds of younger people. (Dewar et al., 1995)

On the basis of the American measurements, it typically takes 10.8 seconds for an elderly pedestrian to cross a 10 m wide signalised junction, in contrast to only 8.8 seconds for a younger pedestrian.

In England, the behaviour of over 11,000 pedestrians was analysed at three busy shopping streets without pedestrian crossings. Elderly pedestrians stopped more often at the kerb, exhibited longer waiting times and turn their heads more frequently before starting to cross the road. On the other hand, they turn their heads less frequently while crossing the road than do young people. No differences were observed between the age groups from the standpoints of crossing the road diagonally, crossing close to parked cars and crossing the road when the gap in the traffic is too small to do so in safety. (Grayson and Wilson, 1980; cited in Hagenzieker, 1996 and Huang et al., 1993)

A Swiss study of 880 pedestrians at a give-way pedestrian crossing on a 2-lane road showed that 60 to 70% of the elderly failed to turn their heads before and while crossing the road. A vehicle was approaching the pedestrian crossing in one third of these cases. It was the elderly, in particular, who failed to watch for traffic. When pedestrians crossed the first half of the road, about 80% of the motor vehicles braked or stopped. On the other hand, it was relatively clear that 20% were unwilling or reluctant to brake or stop. It was more dangerous to cross the second half of the road as only 25% of the motor vehicles braked or stopped. In a quarter of the critical situations, which occurred on the second half of the road, the pedestrian reacted by walking faster. In two thirds of the critical situations, the drivers of motor vehicles were compelled to brake or stop. (Ewert, 1994)

An English experimental study attempted to describe differences in people's spatial and depth perception. The 181 test subjects were between 60 and 86 years old. In the first task, the test subjects were to press a button at the instant a car (which was driving in daylight, at different speeds in the individual tests) reached a cone. The tests were conducted with the aid of a video recorder in a test room. The average error in the tests (time elapsing between pressing the button and the arrival of the vehicle) proved to depend on the subject's ability to think logically and on the subject's experience of driving a car. The better the subjects' abilities and the greater their driving experience, the smaller the average error. On the other hand, the errors were not directly dependent on age or sex. The psychological test showed that the capacity for logical thought starts to diminish at the age of 50, although the range of this capacity was greater within the individual age groups than between the different age groups. The amount of driving done also diminishes from the age of about 55 to 60 and many older women do not drive a car. The second task was more complex. It consisted of estimating the arrival of a car at a cone (with different speeds in the individual attempts) but, in this case, the video film blacked out at 20 or 60 metres before the cone. The results showed that the test subjects were good at judging the distance between the car and cone when the speed was less than about 50 or 60 km/h, but were increasingly late in pushing the button when the speed increased. Once again, it turned out that the errors depended on the subject's capacity for logical thought and driving experience. (Carthy et al., 1995)

The elderly often display compensatory behaviour as road users, thus reducing the effects of physiological and psychological deterioration on road safety. This compensatory behaviour is relatively evident from the accident figures (police recorded accidents 1993-1995) in these examples:

- 44% of pedestrians aged less than 75, who were involved in accidents at signalised junctions, were injured while crossing against a red light. Of the elderly, only 34% were injured when jay-walking.
- On and near zebra crossings, 86% of the elderly accident victims were injured while actually on the crossings. The figure for pedestrians aged less than 75 is 79%. Surveys show that it is more hazardous - in most places - to cross the road in the vicinity of a zebra crossing than on the crossing itself (TØI, 1989).
- Only 2% of the elderly pedestrians involved in accidents are injured while standing on the carriageway, although this figure is 7% for pedestrians aged less than 75.

A British survey of 28 signalised pedestrian crossings showed that people aged 60 and above crossed more often on a green light and more often on the crossings themselves in comparison to younger people (Preston, 1989).

On the surface, the accident figures clearly seem to show that the compensatory behaviour of the elderly is not completely general:

- 2.6% of casualties among the elderly occur in connection with boarding or alighting vehicles, primarily buses, although the figure for the under -75s is 0.6%. The elderly have greater difficulty in boarding and alighting buses. Smaller differences in level, more visible edges and more time for boarding and alighting could perhaps be appropriate solutions.
- 8% of casualties among elderly pedestrians occur in connection with reversing vehicles, whereas the figure for the under -75s is 3%.

In North Carolina, USA, 10% of the elderly pedestrian victims (aged 65 and above) were injured in accidents involving reversing vehicles, whereas the corresponding figure for younger people was only 4%. This means that the elderly are also over-represen-ted in accidents with reversing vehicles in the USA (Huang et al., 1993).

Researchers often point out that the elderly have relatively more difficulty with junctions than with road links in comparison to other age groups. 38% of casualties among the elderly pedestrians occurred at junctions, whereas the corresponding figure for people aged between 25 and 64 was only 32%. If we consider only accidents with crossing pedestrians, we find no differences in the distribution of accidents at junctions and on links between the elderly and the middle-aged, see Table 12.

	Percentage of pedestrian casualties at junctions

Ribbon development	5-8 years	25-64 years	75+ years
Multi-storey buildings	31%	55%	56%
Shopping	40%	53%	54%
Detached housing	22%	41%	37%
No frontage	38%	60%	58%
No buildings	15%	33%	39%

Table 12 *The share of pedestrian casualties at junctions of accidents with crossing pedestrians, on roads with different types of ribbon development for selected age groups. Source: Police recorded accidents 1986-95.*

Table 12 shows, for instance, that 56% of casualties on roads with multi-storey buildings among crossing pedestrians aged over 74 years, were injured at junctions. When compared to the high own risk of the elderly, Table 12 indicates that the elderly experience difficulty in crossing roads both at junctions and on links. The Swiss and English behaviour studies tend to indicate that the traffic behaviour of the elderly presents difficulties whether or not there are zebra crossings. Chaloupka (1994) has attempted to give an overall description of the difficulties of the elderly in crossing roads, see Figure 21.

Accident statistics	Elderly pedestrians cross the street without regarding the oncoming traffic	
Behaviour observation	Elderly pedestrians often have to look down at the road surface trying to find out how big the step will be from footway to carriageway.	They wait for a big gap, after some time they just walk.
Subjective view	• I am afraid of falling down • I don't see well but I don't want to ask for help - otherwise they think I am old and incompetent.	• Cars approach so quickly so that I don't dare to start walking. • I get frustrated when nobody stops for me, so I just start to walk - they have to brake!
Physical condition	• Elderly do not see long enough • Peripherical vision is reduced • Accommodation between near and far lasts longer.	• Problems in distance and speed assessment because of the previous mentioned impairments.
Social environment	Because of a historical development in our society elderly people often are looked at as being incompetent in various areas of life.	They are seen as "hindrances" in our "speed"-world; this leds to negative attitudes towards them and furtheron to a lack of willingness to support them.

Figure 21 *Which problem aspect do the different sources touch? (Chaloupka, 1994)*

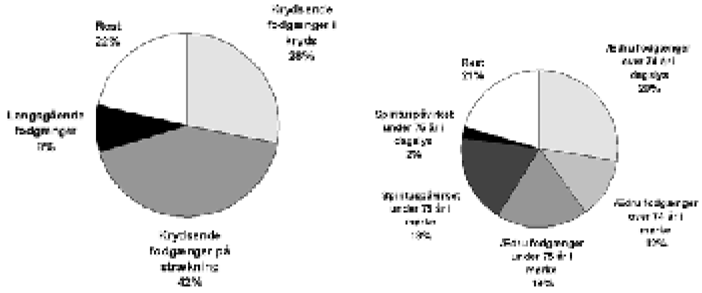
It is difficult to point to conditions that would be especially beneficial to the safety of elderly pedestrians. According to the information of the accident registration form, accidents with elderly pedestrians do not differentiate themselves clearly from accidents involving younger pedestrians. However, 69% of casualties among elderly pedestrians occur on roads with multi-storey buildings and shops, whereas only 53% of casualties in other age groups occur on such roads. 67% of elderly pedestrian casualties are wo-men, in contrast to the normal 49%.

4.7 Summary

About 75% of pedestrian accidents occur when a pedestrian is in the process of crossing a road. The main task is, thus, to reduce the risks to crossing pedestrians. Other vital tasks include making pedestrians more visible in darkness and launching information campaigns on alcohol and pedestrian accidents.

Over a ten-year period, the trends in pedestrian casualties in urban and rural areas have diverged. Thus, an increasing proportion of casualties among pedestrians occurs on roads in rural and industrial areas, which traditionally lack such beneficial facilities as footways, road lighting and pedestrian crossings. A strategy is needed for reducing pedestrian casualties on roads with little pedestrian traffic.

The following description can be given of pedestrian fatalities:



It can be seen from Figure 22 that only 21% of pedestrian fatalities were sober, under 75 years of age and killed in daylight. Important target areas in avoiding pedestrian fatalities include accidents with the elderly pedestrians, pedestrian accidents in darkness and accidents with intoxicated pedestrians. The risk of being killed per walked km is significantly higher for the elderly, during the hours of darkness and under the influence of alcohol.

The number of casualties per walked km is about 2.7 times greater in darkness than in daylight in urban areas, and 7.4 times greater in rural areas. Pedestrians' own risk is about 40% lower in rural areas in comparison to urban areas, which is probably because the number of junctions per walked km is higher in urban areas. However, pedestrian accidents occurring in urban areas are less serious.

The elderly pedestrians who are involved in accidents are injured more seriously than younger pedestrians. Special safety problems for the elderly include reversing vehicles and boarding and alighting buses. Small children have particular safety problems when crossing road links, and especially on links with parked vehicles. There are otherwise no major differences in the accident picture between the age groups.

The audible warning emitted by large vehicles while reversing seems to have had a favourable effect on pedestrian safety. Recessed stop lines for motorists and improved lighting at signalised junctions can improve the safety of pedestrians. The installation of road lighting is expected to improve the safety effect for pedestrians by about 45%, as far as accidents occurring in darkness are concerned, and this effect is expected to be greatest on roads where the speed limit exceeds 50 km/h.

Pedestrian accidents in which cyclists are the counterparts are a relatively large problem, as these accidents constitute about 10% of all pedestrian casualties recorded by the police and as much as 28% of the casualties recorded by hospitals. It is characteristic of these accidents that pedestrians overlook cyclists approaching from their left-hand sides, whereas cyclists do not observe pedestrian rights-of-way at signalised junctions and bus stops or they cycle illicitly on footways, footpaths and pedestrian streets

5. Physical measures and pedestrian safety

Most of the surveys reviewed in the chapter are either before-and-after studies or with-without studies. In a before-and-after study, the number of accidents occurring before and after the implementation of a measure are compared. Big studies often make use of a control group to forecast the number of accidents that would occur during the after period, if the measure had not been implemented. With-without studies compare localities with and without a given measure, e.g., a zebra crossing. Considerable uncertainties are inherent in with-without studies because it is difficult to find localities which only differ from the standpoint of the measure being studied and because it is often necessary to use exposure models which, themselves, contain significant inherent uncertainties.

Grayson and Inwood (1979) tested several different accident models for forecasting the number of accidents involving crossing pedestrians on road sections. The following model was best able to forecast the true number of accidents:

Pedestrian accidents/year = $a \times P^{0.25} \times V$,

where "a" is a constant which describes the "safety level" of a road, "P" is the number of crossing pedestrians and "V" is the number of motor vehicles on the section. The reason for starting this chapter with this formula is that high-level traffic planning is decisive for the number of pedestrian accidents. The formula states that the number of pedestrian accidents is linearly dependent on the number of motor vehicles, whereas it is considerably less dependent on the number of pedestrians. Bearing this in mind, the risk to pedestrians can be reduced by increasing the safety level for pedestrians and/or by reducing the quantity of vehicular traffic on roads where there is much pedestrian traffic. This chapter is mainly devoted to describing physical measures that can contribute to the improvement of the safety level. The safety effects of constructing footpaths and pedestrian streets (where the quantity of vehicular traffic is extremely limited) are also described.

Examples of the ascertained safety effects for pedestrians of various measures described in Chapters 3 to 5 can be found at the end of this chapter.

5.1 Footway

The Danish Road Traffic Act contains no definition of footway or footpath. Despite this, the Act states that pedestrians shall use footways, footpaths or shoulder, although not median strips. Cycle paths and carriageways can only be used in the absence of footways, footpaths or suitable shoulder. In this section, footway denotes a pedestrian area which is raised above the carriageway by about 10 to 20 cm and is separated therefrom by a kerbstone and/or shoulder (less than 1 m).

An American study of pedestrian risks in different areas with and without footways showed that the risk to pedestrians in areas without footways was more than twice as high as in areas with footways. Housing estates which lacked footways accounted for 23.4% of pedestrian accidents, but for only 2.3% of pedestrian traffic. The safety gain was especially large in dedicated housing estates and in multi-functional areas with housing, whereas no effect could be observed in commercial areas. (Knoblauch et al., 1988; cited in ITE, 1994)

The own risk for pedestrians walking along roads in urban and rural areas has been estimated in Section 4.2. The risk incurred in walking a single kilometre along a road is about 40% lower in urban areas than in rural. A number of circumstances other than the presence/absence of footways, such as road lighting and lower speed limits, could be reasons for this lower risk.

Surveys indicate that the construction of footways significantly improves pedestrian safety, although it is not possible to state a specific effect.

5.2 Combined and two-way footpath and cycle path
In this section, footpath denotes a pedestrian area separated from the carriageway by a ditch, a broad shoulder, a guard rail, a fence or suchlike. As a rule, footpaths are combined foot- and cycle paths.

A joint Nordic before-and-after accident study of the construction of 271 km combined and two-way footpaths and cycle paths showed that the number of injury accidents with pedestrians dropped significantly by 37%. The effect was greatest during the hours of darkness. There was no study of changes in quantities of pedestrian traffic. (Kallberg and Salusjärvi, 1982)

A 37% drop in the number of injury accidents with pedestrians was achieved through the construction of combined, two-way footpaths and cycle paths.

5.3 Pedestrian street
According to the Danish Road Traffic Act drivers using pedestrian streets shall be especially vigilant for, and considerate to, pedestrians.

The conversion of Slotsgade in Hillerød, from an ordinary shopping street into a pedestrian street along part of its length or else a traffic-calmed road, caused the number of pedestrian accidents and casualties to drop by 100% on the road itself, although no changes in safety were observed on adjoining and parallel roads. If we consider all accidents involving all types of road user, the reconstruction of Slotsgade resulted in a significant reduction. (Værø, 1992)

The conversion of Røldalsvegen, Odda Centrum, Norway, from an ordinary shopping street (with two-way traffic permitted for all vehicles) to a pedestrian street, resulted in a drop from 2.8 accidents/year in the before period, to 0.5 accidents/year in the after period. This represents a drop of 82%. No attempt has been made to distribute the accident saving over types of accident. (Norwegian Road Directorate, 1988)

During the years 1993-1995, the police recorded 7 injury accidents with pedestrians a year on the more than 100 Danish pedestrian streets. For the sake of comparison, they also recorded 10 injury accidents with pedestrians a year on Danish motorways.

The conversion of roads which carry two-way vehicular traffic into pedestrian streets has resulted in drops of 82 to 100% in the number of pedestrian accidents occurring on the reconstructed roads.

5.4 Conversion of two-way street into one-way street
Three American studies has shown that the number of pedestrian accidents can be reduced by converting two-way streets into one-way streets. The number of pedestrian accidents dropped by 62% in Sacramento after 19 streets in the city centre were converted. The number of pedestrian accidents dropped by 38% in Hamilton after 43 km of road sections were converted to one-way streets. Converting a number of streets in Manhattan, New York, resulted in a drop of 34% in the number of pedestrian accidents. None of the studies offers any information on changes in the quantities of car traffic. (Zeeger and Zeeger, 1988)

Conversion of two-way streets into one-way streets has led to a fall in the number of pedestrian accidents of 34-62%.

5.5 Zebra crossing
According to the Danish Road Traffic Act, a zebra crossing is a part of the road, which is provided for pedestrians when crossing the carriageway or cycle path and which is specially marked. If there is a zebra crossing in the vicinity, pedestrians must use it when crossing carriageways or cycle paths. Drivers approaching a non-signalised zebra crossing must adapt their speed so as to avoid danger or inconvenience to pedestrians who are crossing or who are just entering the crossing. If necessary, drivers shall stop to allow pedestrians to pass. Vehicles must not stop or park on zebra crossings or park within a distance of five metres before them. Drivers approaching a zebra crossing must not overtake or pass another vehicle if that vehicle obstructs a full view of the crossing.

In Denmark, zebra crossings consist of broad stripes which are parallel to the direction of the road. On road sections, zebra crossings must be a minimum of four metres wide and at junctions, a minimum of 2.5 metres wide. Non-signalised zebra crossings must not be established on roads where the speed limit exceeds 60 km/h. The Danish type of zebra crossing is also used in other countries. Other countries also have other types of pedestrian crossing and other traffic rules.

The risk to pedestrians crossing roads at various points in traffic systems has been studied in a series of studies from England (Mackie and Older, 1965; Jacobs and Wilson, 1967), Denmark (Jørgensen and Rabani, 1971), Norway (Giæver and Vodahl, 1986) and Sweden (Ekman, 1988). The same method was used in all these studies. The number of accidents in which crossing pedestrians was involved was compared to the number of pedestrians crossing with a fixed period (12 min. counts outside the rush hour were used). The risk assessments of the individual studies were based on relatively modest input data. One study found that the risk involved in crossing road sections at up to 45.7 metres from a zebra crossing including the crossing itself was 30% higher than that at over 45.7 metres from a zebra crossing, whereas three other studies found that the risk was up to 50% lower. Three studies found that the risk involved in crossing roads at or near non-signalised junctions, at distances of up to 18.3 metres from the junctions and up to 45.7 metres from a zebra crossing was up to 127% higher in comparison to that at non-signalised junctions lacking zebra crossings, although two other studies found that the risk was up to 35% lower. The effects of other circumstances, such as central islands, road lighting and road width were not eliminated in the studies.

The risk to crossing pedestrians in the Norwegian and Swedish studies was estimated for areas of up to 18.3 metres from three- and four-armed junctions; see Table 13. For junctions with zebra crossings, this area was divided into three zones as shown in the figure in the margin. It should be noted that some of the signalised junctions in the Norwegian study had a separate phase for pedestrians (scramble).

	Trondheim (Norway)		4 Swedish towns	
Type of control	Non-signalised	Signalised	Non-signalised	Signalised
1) Between junction and zebra crossing	0.00	0.62	0.41	1.29
2) On zebra crossing	1.00	1.00	1.00	1.00
3) "After" zebra crossing and up to 18.3 metres from junction	5.16	1.57	1.08	3.38

Table 13 *Relative risk to pedestrians crossing up to 18.3 metres from junction, where the risk of crossing the road on the zebra crossing is set to 1.00. The original figures of the sources have been converted, although they are comparatively uniform between the zones. (Giæver and Vodahl, 1986; Ekman, 1988)*

Table 13 indicates that the risk to crossing pedestrians increases, the further from the junction they cross the road. The safety effect of zebra crossings at junctions depends, therefore, on where they are located. If a zebra crossing is located close to a junction it can improve pedestrian safety, but if it is located at some distance from the junction it can diminish pedestrian safety. Ekman (1988) also emphasises that pedestrian crossings should be located as close to junctions as possible.

Gårder et al. (1978) found from conflict studies conducted at 115 junctions in Malmö and Stockholm that the risk to pedestrians was lowest when zebra crossings were marked either less than 2 metres or more than 10 metres from the near side of the intersecting road. The risk was twice as high (significant) when zebra crossings were marked at between two and ten metres of the near side of the intersecting road, in comparison to marking at less than two metres from the intersecting road.

In New Zealand, the risk to crossing pedestrians has been found to be 15% lower at non-signalised zebra crossings, in comparison to crossing roads at any other point. Pedestrian exposure was estimated through interviews. No allowance was made for possible differences in the occurrence of other measures, quantities of car traffic and speed of car traffic. (Keall, 1995)

A before-and-after study of the construction of 62 zebra crossings in London showed that the safety effects of the crossings was dependent on the accident rate (all accidents) during the before period. At places where there had been fewer than 2 accidents/year on a 100 metre section with the crossings located at the centres of the sections, the number of pedestrian accidents increased significantly by 50%. In contrast to this, the number of pedestrian accidents dropped significantly by 50% on sections where there had been more than 3 accidents/year. There was an attempt to reduce the effects of bias in the results. (Landles, 1983)

An American with/without accident study of pedestrian crossings marked with 2 continuous white lines (parallel to the stop lines, but without zebra stripes) at 400 non-signalised junctions showed that the risk to crossing pedestrians was about twice as high at the pedestrian crossings in comparison to unmarked crossings. The pedestrian crossings at the 400 junctions were marked only on one arm of the primary road, whereas the other arm was unmarked. Only pedestrian accidents occurring at the crossings themselves were included in the study, which is critical, as the location of the unmarked crossings must therefore be determined and accidents occurring in the vicinities of the crossings are important in a risk assessment. The traffic was counted for 24 hours at 40 systematically-selected junctions. At these 40 junctions, the risk to crossing pedestrians was only 40% higher at pedestrian crossings in comparison to unmarked crossings. (Herms, 1972)

Draskóczy and Hydén (1994) point out that the give-way rules possibly influenced the effect of the pedestrian crossings. Even though most studies indicate a negative safety effect of pedestrian crossings, there are exceptions, e.g., from England and Norway. England and Norway have clear give-way rules which require vehicles to give way to pedestrians, whereas other countries, such as Sweden and the USA have no such rules.

Draskóczy and Hydén thus suggest that the clear give-way rules in the Danish Road Traffic Act, which are mentioned at the beginning of this section, are a contributory factor so that zebra crossings in Denmark should reduce the number of accidents in which crossing pedestrians are involved.

Swiss traffic regulations were amended in 1994, so that vehicles must give way when the behaviour of a pedestrian clearly indicates that he or she intends to use a zebra crossing. Earlier, pedestrians needed to signal to drivers that they wished to cross the road. It was possible to conclude on the basis of behaviour studies that the average number of vehicles that drove past before waiting pedestrians crossed the road dropped from 2.6 in the before period, to 1.5 in the after period. The proportion of motorists who stopped/braked and allowed pedestrians to cross the road increased from 12.5% in the before period, to 31.6% in the after period one year after amendment of the give-way rules. (Ewert, 1995)

Based on literature, Várhelyi (1996) writes about non-signalised zebra crossings: :

- The presence of pedestrians at zebra crossings has little or no influence on the speed of approaching vehicles
- Between 4 and 30% of vehicle drivers give way to pedestrians at zebra crossings.
- Drivers are more willing to slow down or stop for crossing pedestrians when the approach speed of the vehicle is low.

A Danish interview survey showed that crossing pedestrians feel safer at zebra crossings than they are away from them (Herrstedt, 1981). This should possibly be considered in the context that pedestrians walk about 10% faster when crossing a road away from a zebra crossing than they do at such crossings (Dewar et al., 1995).

Because of differences in design between the countries, behaviour patterns, legislation and rules concerning zebra crossings, it is difficult to assess the safety effect of constructing zebra crossings in Denmark. Effects of up to ±50% on the number of accidents involving crossing pedestrians have been attained or estimated through the construction of zebra crossings on road sections. Zebra crossings on road sections should be marked at the point where it is safest for pedestrians to cross the road. Reductions of up to 35% and increases of up to 127% in the number of accidents involving crossing pedestrians have been attained or estimated through the construction of zebra crossings at non-signalised junctions. At junctions, zebra crossings give the best safety effect for pedestrians when they are located as close to the intersecting road as possible. When located optimally, zebra crossings should be considered by pedestrians to be "guides to the safest route".

5.6 Footbridge and underpass

According to the Danish Road Traffic Act, footbridges or underpasses should be used whenever possible for crossing carriageways and cycle tracks, provided that there is such a facility nearby.

A Japanese study dating from 1969 discusses the safety effects attained through the construction of 31 footbridges. The number of pedestrian accidents dropped by 85% on a 400-metre road section with the bridge at the centre, whereas there was a 91% drop on a 200-metre section with the bridge in the centre. Both drops were significant. (Zeeger and Zeeger, 1988)

This safety effect depends on the utilisation of footbridges or underpasses. If it is faster to use the bridge for crossing the road than an alternative route on the ground, over 70% of pedestrians will use the bridge. 70% of pedestrians use the underpass, even if it takes 25% more seconds to cross the road by underpass in comparison to an alternative route on the surface. (Zeeger and Zeeger, 1988)

Dernellis and Ashworth (1994) demonstrate a clear relationship between the quantity of vehicular traffic and the proportion of pedestrians who use underpasses on road sections where it is otherwise possible to cross the road in other ways (no fence, guard rails or suchlike). At a traffic flow rate of about 200 to 250 vehicles/5 minutes, 90 to 100% of the pedestrians use the underpass, whereas at about 50 vehicles/5 minutes, only 70% of the pedestrians use it. The distance to signalised zebra crossings and the design of the underpass are, however, relatively significant to utilisation. This study was conducted in central Sheffield, England.

The construction of footbridges has led to reductions of 85% in the number of pedestrian accidents occurring at up to 200 metres from the bridges. Their safety effect depends on the degree of utilisation.

5.7 Traffic island and pedestrian refuge

A joint Nordic before-and-after accident study of traffic islands in the side road at 53 non-signalised junctions showed that the number of pedestrian accidents at 4-armed junctions increased from 0 to 4, whereas the number at T-junctions dropped from 3 to 2. The effect on the total number of accidents was a significant reduction of 49% at 4-armed junctions, and a non-significant increase of 7% at T-junctions. (Schiøtz, 1982)

A before-and-after accident study of pedestrian refuges in London showed that refuges provide different safety effects for pedestrians at priority junctions and on sections, respectively. The “double D”-shaped traffic islands in the centre of the road were constructed during the period 1970-1975. Five studies were undertaken:

- Study 1: Pairs of refuges and GIVE WAY signs were placed in the side road in 11 priority junctions resulting in a drop from 11 to 8 in the number of pedestrian accidents, whereas the total number of accidents dropped from 109 to 49.
- Study 2: Out of consideration for traffic flow, refuges were installed in 62 priority junctions. In this case, the number of pedestrian accidents increased from 41 to 53, whereas the total number of accidents dropped from 161 to 157.
- Study 3: Installing single refuges at 23 sites on road sections not near junctions resulted in a drop from 15 to 11 in the number of pedestrian accidents, whereas the total number of accidents dropped from 46 to 37.
- Study 4: 37 refuges were installed on 5 road sections, which resulted in an increase from 12 to 13 in the number of pedestrian accidents and an increase from 47 to 51 in the total number of accidents.
- Study 5: Pedestrian refuges were installed at 19 zebra crossings on road sections. The number of pedestrian accidents dropped from 56 to 37 and the total number of accidents, from 124 to 103.

The safety effects for pedestrians were not statistically significant in the five studies. Overall, the construction of pedestrian refuges resulted in a non-significant increase of 17% in the number of pedestrian accidents at priority junctions and a significant drop of 27% in the number of pedestrian accidents on road sections. (Lalani, 1977)

In a British study of non-signalised zebra crossings, 51 crossings lacked pedestrian refuges and 33 had refuges. By making allowance for the pedestrian and vehicular traffic, the risk involved in crossing the road was found to be exactly the same, with or without the refuge. Although road sections with and without refuges resembled each other, there were significant differences. The number of overtakes/hour undertaken by vehicles in the vicinities (less than 18 m) of the crossings were eight times higher at crossings with pedestrian refuges, which indicates a considerable difference in the speed scatter. The road that the pedestrians were to cross was also broader at crossings with refuges, which means that the pedestrians were exposed for longer periods. Speeds were not measured. It is therefore not inconceivable that the construction of pedestrian refuges at zebra crossings considerably reduces the risk to pedestrians. (Grayson and Inwood, 1979)

An Australian before-and-after accident study of the construction of pedestrian refuges at priority junctions in the centre of four-lane major roads showed that the refuges reduced pedestrian risk by 12% (Western Roads, 1978; cited in ITE, 1994).

The zebra crossings were removed from 25 road sections in Perth, Australia, and replaced by pedestrian refuges in the centre of the road without marked crossings. The number of pedestrian accidents dropped from 26 in the one-year before period prior to 5 in the one-year after period. The number of collisions between vehicles dropped from 79 to 13. Pedestrians used the crossings with refuges in the same way they had used the removed zebra crossings. (Gallop, 1989)

Conflict studies of 115 junctions in Sweden, conducted during the period 1974-1976, showed that the risk of serious conflicts with pedestrians at priority junctions, where the median speed of the vehicles was less than 30 km/h, were about 20% lower when central traffic islands were present. At priority junctions where higher speeds prevailed, the risk of serious conflicts with pedestrians was about 60% lower when central traffic islands were present, whereas the risk at signalised junctions (two phases) was about 30% lower with central islands. The effects are not statistically significant. (Gårder et al., 1978)

Kulmala (1982) found from conflict studies that the risk to pedestrians in Finland was about 60% lower when central traffic islands were present.

One study found a 50% increase in the number of pedestrian accidents after the installation of traffic islands in the side road, whereas another study found a 27% drop. The construction of pedestrian refuges on the major road at priority junctions, at signalised junctions and on road sections reduced the number of pedestrian accidents by up to 81% and increased that number by up to 29%.

5.8 Central reserve

Traffic calming was implemented in Østerbro, Copenhagen, in the mid-1970s. In this connection, a central reserve with kerbstones was established on part of Østerbrogade. In another part of Østerbrogade a central reserve, which had traffic islands demarcated by kerbstones at junctions, was marked on the road. The safety effect for pedestrians was that the number of accidents involving pedestrians crossing Østerbrogade on road sections dropped significantly from 17 to 3, which corresponds to an 82% drop. (Engel and Thomsen, 1983)

A marked central reserve with islands demarcated by kerbstones was constructed on a major road in Australia. The number of pedestrian accidents dropped from 7 to 3, which corresponds to a 57% drop, despite the fact that the annual daily traffic increased from 14,000 vehicles/day to 21,000 (Gallop, 1989).

The construction of central reserves has resulted in drops of between 57 and 82% in the number of accidents involving crossing pedestrians.

5.9 Raised area
Six raised areas (5.5 metres wide pedestrian ramps) were constructed on a road in the centre of Milton Keynes, England, in 1988. Signs giving a recommended maximum speed of 16 km/h were posted and ramps at the raised areas were marked with white triangles. An interview survey revealed that as the raised areas were not marked with zebra stripes, pedestrians were in doubt as to who had the right of way. The road carried over 7,000 vehicles, and more than 18,000 pedestrians crossed the road, between 12:00 and 19:00 on Thursday, in other words, a busy road. After construction of the raised areas, the vehicular traffic dropped by 12% and the average speed, from 42 to 24 km/h. 93% of the pedestrians crossed the road at the raised areas. The number of pedestrian accidents dropped significantly by 92% and the number of other accidents dropped significantly by 62%. (Farmer and Jones, 1993)

5.10 Fence and guard rails
Two studies have been reviewed by Zeeger and Zeeger (1988). The number of accidents involving pedestrians crossing on road sections dropped significantly after the erection of fences on central reserves. The installation of guard rails between footways and carriageways on 18 road sections in Tokyo, Japan, reduced the total number of pedestrian accidents at junctions and on sections by about 20%

Two before-and-after studies of injury accidents in London showed that ordinary guard rails on the central reserves led to a 20% reduction in the number of pedestrian accidents, whereas there was a 48% reduction when the guard rails were of a type that obstructed the view to a lesser extent. Ordinary guard rails can obscure motorists' views, e.g., of children and wheelchair users, and vice versa. (Stewart, 1988)

5.11 Signalised pedestrian crossing on road section
Apart from signalised junctions, traffic-signal control is also used for zebra crossings in exceptional cases, where it is necessary to establish a zebra crossing on a road which carries fast traffic or which is very trafficked, or where there are many pedestrians during only certain daylight hours (free quotation from the Danish Road Rules).

A Nordic before-and-after accident study of the application of signal control to 112 zebra crossings on road sections, some of which already had pedestrian refuges, found a 35% significant drop in the number of pedestrian accidents, whereas the number of other accidents dropped by 8%. The total number of accidents only dropped on roads carrying more than 12,000 vehicles/day. (Kildebogaard and Wass, 1982)

The conversion of 7 zebra crossings to traffic-signal control in Trondheim, Norway, led to a fall in the number of pedestrian accidents, from 5 to 4, i.e., a 20% reduction (Giæver, 1987).

Pelican crossings are signalised pedestrian crossings, which lack zebra stripes but which have stop lines for the vehicles, on road sections. The traffic signals are usually controlled by pedestrian push-buttons and vehicle detection. Pelican crossings are not permitted in Denmark. A before-and-after accident study of the construction of 38 pelican crossings in Great Britain showed a minor increase in the number of pedestrian accidents, from 100 during the before period to 106 afterwards (Rayner, 1975). A similar before-and-after accident study in Great Britain, in which non-signalised zebra crossings converted into pelican crossings, showed an 11% drop in the number of pedestrian accidents (Bagley and Fletcher, 1985). A before-and-after accident study of three pelican crossings on road sections in Perth, Australia, showed no change in the number of pedestrian accidents. There were four pedestrian accidents in both the before and after period (Willett, 1977).

At or within 50 metres of a pedestrian crossing facility	Primary and district distributors	Local distributors	Residential roads and major driveways	All roads
No facility or dropped kerb	427*	155*	18*	56*
Zebra crossing	5	38	-	28
Pelican crossing	226*	200	-	217*
Other signal controlled installation with pedestrian phase	173*	68	6	125*
School crossing patrol	-	72	30	53
Refuge	83*	19	5	46*
All locations	214*	118*	18*	63*

Table 14 *Pedestrian casualty rates per 100 million crossings on or within 50 metres of pedestrian crossing facilities on different types of road in Northampton. *Accident rate is based on more than 20 casualties. (Allsop et al, 1994)*

A study of pedestrian risk in Northampton, England, also found that pelican crossings have a positive safety effect. This study was based on 782 pedestrian casualties and 737 home interviews, in which the trips of the respondents were described in great detail. Some of the results of this study are shown in Tables 14 and 15. It can be seen from Table 14 that the own risk for pedestrians is 47% lower at pelican crossings than at points which lack pedestrian facilities on primary and district distributors. Other signalised pedestrian crossings, which are primarily encountered at four-armed junctions, and crossing points which have pedestrian refuges are apparently safer than pelican crossings. (Allsop et al., 1994)

Table 15 shows that it is safer to cross roads at junctions than on sections. We should add that 14% of the casualties at T and Y junctions occurred at signalised junctions, similarly 69% at crossroads and 63% at multiple junctions. (Allsop et al., 1994)

	Primary and district distributors	Local distributors	Residential roads	All roads
Not at a junction	429*	164*	61*	130*
Within 20 metres of ...				
T or Y junctions	196*	97*	11*	42*
Crossroads	210*	37	10	68*
Roundabouts	17	21	12	29
Multiple junctions	83*	13	14	51*
All junctions	153*	51*	10*	38*
All locations	215*	109*	21*	66*

Table 15 *Pedestrian casualty rates per 100 million crossings on different types of road at or within 20 metres of junctions of various types in Northampton. *Accident rates based on more than 20 casualties. (Allsop et al, 1994)*

Installation of traffic signals at zebra crossings on road sections has led to reductions of 20 to 35% in the number of pedestrian accidents. Pelican crossings have been ignored.

5.12 Signalised junction
TØI (1989) states that the installation of traffic signals at junctions reduces the total number of accidents by between 20 and 40%. Moreover, the accident-reducing effects of traffic-signal control are apparently the same at crossroads as at T and Y junctions. Accidents between vehicles in intersecting directions and accidents with pedestrians are generally reduced most.

The installation of traffic-signal control at 152 junctions in Cincinnati, in the 1950s, had the following effects: the number of pedestrian accidents was unchanged at 90 junctions, increased at 30 junctions and decreased at 32 junctions (Zeeger and Zeeger, 1988).

At priority junctions where the speed level is low (median speed of motor vehicles is less than 30 km/h on all approach roads), conversion to traffic-signal control reduces the risk to pedestrians by about 30% (not statistically significant), on condition that most vehicles do not turn at the junction. The effect is considerably greater at junctions where the speed level is higher, i.e., the risk is reduced by about 70%. Results have been found by using the conflict technique at 115 junctions in Sweden. (Gårder et al., (1978).

Reductions of between 0 and 70% in the number of pedestrian accidents have been attained or estimated through the installation of traffic-signal control at junctions.

5.13 Separate phases for pedestrians
The installation of separate pedestrian phases at signalised junctions (also known as scramble) reduced the number of serious conflicts with pedestrians by about 63% in two Swedish junctions, which was statistically significant. An American before-and-after accident study at 50 junctions in Denver showed that the number of fatalities dropped, from 7 in the before period to 0 after the installation. A before-and-after study from the USA showed that the installation of a separate phase for pedestrians resulted in a 47% drop in the number of pedestrian accidents. (Gårder, 1982)

The risk involved in crossing the road at junctions with a separate phase for pedestrians was statistically significantly lower when the number of crossing pedestrians exceeded 1,200/day/junction, in comparison to traditional, two-phase, signalised junctions with or without signals for pedestrians (walk/don't walk or red/green man). This study covered 1,297 signalised junctions in the USA, of which 109 had separate phases for pedestrians. Altogether (including junctions where there were few crossing pedestrians), the risk of crossing the road at junctions with separate phase for pedestrians was 42% lower than at traditional signalised junctions. The study also showed that pedestrian signals (such as red/green man) had no effect on the number of accidents in which crossing pedestrians were involved. It was the separate phase for pedestrians itself which had the effect. (Cynecki et al., 1982a)

The installation of separate phases for pedestrians at 11 signalised junctions in New York City, USA, resulted in a drop of from 27 to 25, corresponding to 7%, in the number of pedestrian accidents (Cynecki et al., 1982b).

Reductions between 7 and 63% in the number of pedestrian accidents have been attained or estimated through the installation of separate phases for pedestrians at junctions.

5.14 Road lighting
The installation of road lighting in the USA has led to a reduction of about 43% in the number of pedestrian accidents occurring during the hours of darkness (Huang et al., 1993). Two other studies from the USA show that the installation of road lighting led to reductions of 35% and 42%, respectively, in the number of pedestrian accidents occurring in darkness (Zeeger and Zeeger, 1988).

An Israeli study dating from 1978, in which road lighting was installed on 99 road sections, showed that the number of pedestrian accidents occurring in darkness dropped from 28 to 16, which corresponds to a 43% drop (Katz and Polus, 1978).

Earlier in this report, the installation of lighting was estimated to reduce the number of pedestrian casualties occurring in twilight and darkness by about 45%, but only on roads where the permitted speed exceeds 50 km/h.

Reductions of from 35 to 45% in the number of pedestrian accidents occurring in darkness have been attained or estimated through the installation of road lighting.

The improvement of existing road lighting of low-standard has an accident-reducing effect, whereas the reduction of road lighting (as an energy-saving measure) increases the number of accidents (TØI, 1989). Foyster and Thomson (1986) found a 16% drop in the number of pedestrian accidents as a result of improving existing road lighting.

5.15 Improved lighting at zebra crossing
The installation of better lighting at zebra crossings, i.e., the so-called "Copenhagen system", has been estimated to give a 30% reduction in the number of pedestrian accidents occurring in darkness. This system can help to make pedestrians more visible and can induce them to cross the road at a zebra crossing, in preference to a point elsewhere in the immediate vicinity. The system consists of road markings, a flashing amber light, internally-illuminated zebra-crossing-signs and illumination of the crossing with two 1,000 W lamp suspended about six metres above the carriageway. (Jørgensen and Rabani, 1971)

The installation of floodlights at 63 zebra crossings in Perth, Australia, resulted in a significant drop in the number of pedestrian accidents in darkness, from 39 in the before period to 15 in the after period, i.e. a 62% reduction. The installation did not affect the number of pedestrian accidents occurring in daylight and neither did it affect the number of other accidents. The Perth system consists of a 100 W sodium-vapour lamp, suspended about five metres above the carriageway, on either side of the zebra crossing. (Zeeger and Zeeger, 1988)

Reductions between 30 and 62% in the number of pedestrian accidents occurring in darkness have been attained through the improvement of lighting at zebra crossings.

5.16 Reflector
One study indicates that pedestrians who do not wear reflectors run a risk of being killed or injured in darkness that is nine times higher than that of pedestrians who do. This means that reflectors reduce the risk to pedestrians by 89% (TØI, 1989). An analysis of casualties occurring among Danish pedestrians in darkness during the period 1993-1995 reveals that 9% of pedestrians were struck from behind, 13% from in front, 31% on the right-hand side and 24% on the left-hand side. It is, therefor, vital to wear reflectors all round the body.

5.17 Summary
Table 16 lists the safety effects for pedestrians found in the studies reviewed in Chapters 3-5 and in the analyses of Chapter 4. When drafting Table 16, surveys were discarded as they were considered to be remote from Danish construction practice. For instance, the effect studies of pelican crossings are not included in the table. Effect studies of separate phases for pedestrians at junctions are however included, even though this measure cannot be found in Denmark.

Generelt må der tilføjes til tabel 16, at sikkerhedseffekterne er afhængige dels af fodgængernes brug af foranstaltningen dels af mængden af fodgænger- og motoriseret trafik samt af detailudformningen af foranstaltningen. For punktbestemte foranstaltninger som f.eks. fodgængerfelt og midterhelle, er sikkerhedseffekten opgjort for et område op til 50 m fra foranstaltningen. For strækningsbestemte foranstaltninger f.eks. midterrabat og vejbelysning, er sikkerhedseffekten opgjort for selve strækningen evt. indeholdende kryds.

Safety measure	**Types of pedestrian accident under influence**	**Attained/estimated safety effect**
Speed reduction of 0,5-18 km/h[1]	All pedestrian accidents	-17% to 92%[2]
Footway	All pedestrian accidents	Accident reducing[2,3]

Combined, two-way foot- and cycle path[4]	All pedestrian accidents	-37%[2]
Pedestrianisation of street	All pedestrian accidents	-82% to -100%[2]
From two-way to one-way street	All pedestrian accidents	-34% to -62%[2]
Zebra crossing on road link	Accidents with crossing ped.	+50% to -50%
Zebra crossing at priority junction[5]	Accidents with crossing ped.	+127% to -35%[2]
Footbridge[6]	Accidents with crossing ped.	-85%
Side road pedestrian refuge with kerb	All pedestrian accidents	+50% to -27%[2]
Other pedestrian refuge with kerb	All pedestrian accidents	+27% to -81%
Central reserve - marked or with kerb	Accidents with crossing ped.	-57% to -82%[2]
Guard rails on central reserve or at footway	All pedestrian accidents	-20% to -48%
Signalisation of a zebra crossing on road link	Accidents with crossing ped.	-20% to -35%[2]
Roundabout	All pedestrian accidents	-46% to -89%
Signalisation of junction	All pedestrian accidents	-0% to -70%
Exclusive pedestrian signal phase, scramble	All pedestrian accidents	-7% to -63%
Road lighting	Pedestrian accidents in dark	-35% to -45%[2]
Improved lighting at pedestrian crossing	Pedestrian accidents in dark	-30% to -62%[2]
Reflector, reflective strip	Pedestrian accidents in dark	-89%

***Table 16** Attained/estimated safety effects for pedestrians when implementing safety measures. A safety effect of -20% equals a reduction of 20% in the number of accidents. Notes: 1. Average speed reduction of motorized vehicles by changes in permitted speed, increased traffic control, bump, etc. 2. Safety effects based on (among others) Danish studies.; 3. The magnitude of the effect is uncertain. 4. In the before period there was no footway or footpath of any kind. 5. The safety effect of zebra crossings at junctions depends on the location of the zebra to the intersecting road. 6. The safety effect of a footbridge (in this study up to 200 metres away from bridge) depends on the degree of utilisation.*

A general comment to be added to Table 16 is that the safety effects depend on the utilisation of the facilities, on the quantities of pedestrian and vehicular traffic and on the detailed design of the facilities. In the case of facilities at specific focal points, such as zebra crossings and pedestrian refuges, the safety effect has been assessed for an area within 50 metres of the facility. In the case of facilities on road sections, such as central reserves and road lighting, the safety effect has been assessed for the section, itself, and for any eventual junctions thereon.

Table 16 does not constitute a key to safety effects, it is just a list of examples taken from effect studies. The large intervals in the safety effect for pedestrians are due to the differing results of the effect studies.

Against the background of Table 16, it can be seen that pedestrian safety can be improved by the application of well-known measures. However, some of the safety measures shown in Table 16 are already quite common in Denmark, e.g., footways and road lighting.

6. Research and development

This chapter mentions some of the areas in which new knowledge on pedestrian safety can be of relevance.

Travel surveys of school children
The trend in own risk for pedestrians aged 16 years and over has been described in Chapter 2. The trend in own risk for school children is not known. School children's road safety has been in focus over the past 20 years, partly through the 1996 amendments to the Danish Road Traffic Act concerning school roads, and partly through the new opportunities for traffic calming and the subsequent school road projects. It is important to know whether or not this focus has born fruit, in the form of a reduction of the own risk for school children in traffic. Travel surveys from schools in Odense can possibly

be used to clarify the trend in own risk for school children.

Road safety of elderly pedestrians
Every other pedestrian killed in 1995 was over 68 years. There is still some doubt as to why elderly pedestrians should have a higher own risk than younger pedestrians. The elderly receive more serious injuries, for which reason a strategic effort on their behalf can reduce the number of fatalities dramatically. One project could describe the relationships between the accidents of elderly pedestrians, housing and traffic patterns, and determine the "safety level" needed to provide satisfactory road safety for elderly pedestrians.

Pedestrian accidents on high-speed roads
18% of pedestrian casualties and 38% of the fatalities occurred on roads where the permitted speed exceeded 60 km/h in 1995. There is normally only modest pedestrian traffic on these roads, for which reason such costly facilities as pedestrian bridges, pavements and footpaths are often unrealistic in practice. The speeds of vehicles are also too high to permit zebra crossings. Pedestrian accidents on these roads should be studied more closely. An American survey showed that about 32% of the pedestrian fatalities, which occurred on interstate highways, the victims had no intention of remaining on the carriageway, but were walking on it as a result, e.g., of other accidents or of vehicle failures (Johnson, 1997).

Urban traffic management, land use and pedestrian safety
The number of pedestrian casualties per walked km is higher in urban areas than in rural. Own risk is especially high in the cities. Pedestrians cross more roads/walked km in urban areas, which could be the reason for a higher own risk. Urban traffic management can be used to reduce the number of functions of the individual roads, so exposure of pedestrians to other types of traffic can be reduced, e.g., through the construction of pedestrian streets and low-speed shopping streets. When planning land use, facilities that are much used by pedestrians, such as shops and schools, can be located on roads and in areas where there is little vehicular traffic. There appears to be a need for new planning tools for older, multi-functional, urban areas in large towns and cities.

Motorists’ observance of their obligation to give way at zebra crossings
The idea behind zebra crossings is to reduce the risk for crossing pedestrians and to reduce their waiting time. About 26% of pedestrian casualties occur at or near zebra crossings. Only between 4 and 30% of motorists observe pedestrian rights of way at zebra crossings, which means that the waiting times for crossing pedestrians are not noticeably reduced by zebra crossings. Technical approaches that can increase the proportion of motorists who do observe pedestrian rights of way should be investigated more closely.

Safety effects at different speed levels and quantities of traffic
This report contains indications that, when installing zebra crossings, pedestrian bridges and road lighting, the safety effects obtained for pedestrians depend on the speed level of vehicular traffic and the quantity of traffic. It is important to determine the conditions under which such measures result in an improvement in safety.

Pedestrian safety at signalised junctions
I 15% of pedestrian casualties occurred at signalised junctions in 1995. The safety effects for pedestrians of a number of measures should be studied, e.g., recessed stop lines, improved lighting at zebra crossings and the co-ordination of signalised junctions.

Placement of road lighting
The safety effect for pedestrians of road lighting is relatively high, since a large proportion of pedestrian accidents occur in darkness. The actual effect depends on the intensity of the lighting. It is important to clarify the relationships between safety effect and the vertical and cross-sectional location of the lighting. Lighting has a particularly pronounced effect on accidents involving pedestrians who are walking along the road. The illumination of the sides of roads, in contrast to illumination along the middle, would perhaps lead to a greater improvement for pedestrians. Such a study could possibly be considered in the contexts of personal security, crime and road aesthetics.

Significance of alcohol to pedestrian risk
About 20% of pedestrians killed were under the influence of alcohol. It is important to clarify the significance to own risk of pedestrians' blood-alcohol concentrations.

7. Summary and conclusion

This report is based on analyses and literature studies about pedestrian safety. The key topics are; accident and risk developments for pedestrians, pedestrian safety compared to safety of other road users, detailed analyses of pedestrian accidents, and safety effect for pedestrians of several measures. The key results are summarized below:

- The number of pedestrian casualties in Denmark decreased by 26%, from 1,552 in 1986 to 1,151 in 1995. Pedestrian casualties decreased by 30% in urban areas, but remained unchanged in rural areas in the period 1986-1995.
- From 1981 to 1993-95 the number of walked km decreased by about 20%. Joining accident and travel developments, the casualty rate per walked km has decreased by 8% from 1981 to 1993-95. However the 8% is somewhat uncertain.
- The casualty rate per person km is approximately 8 times higher for pedestrians than travel by private car and a

bit higher as cycling - according to accident data collected by the police. Per trip, the casualty rate for pedestrians is much lower than for both cyclists and occupants of private cars. Per person hour, the casualty rate for cyclists is twice as high as for pedestrians and occupants of private cars.
- 70-75% of all pedestrian casualties in traffic areas recorded at hospitals are falls with no vehicles involved. If falls are included in the risk assessment, the casualty rate per trip is twice as high for pedestrians as for occupants of private cars.
- About 75% of police recorded pedestrian accidents occur when a pedestrian is in the process of crossing the road.
- The greatest part of pedestrian casualties occur on urban road links. 84% of pedestrian casualties occurred in urban areas in 1995. The casualty rate per walked km is highest in urban areas. Pedestrian accidents are predominant in big cities.
- High risk groups are; elderly pedestrians, drunk pedestrians and pedestrians in the hours of darkness. Only 21% of pedestrian fatalities involves sober pedestrians, who walked in daylight and was under 75 years of age.
- Special safety problems for the elderly pedestrians include reversing vehicles and boarding and alighting buses. Children aged 5-8 years have safety problems when crossing road sections near parked cars.
- Police tests and assessments of persons involved in injury accidents show that 12% of the pedestrians have a blood alcohol concentration of 0.8 g/l or higher. This is a high proportion compared to 4% drunk cyclists and 8% drunk drivers of private cars.
- Even though 80% of the counterparts in police recorded pedestrian accidents are cars, cyclists is a rather big problem. In 10% of the police recorded and 28% of the hospital recorded accidents between pedestrians and vehicles the counterpart is a cyclist.
- The average speed and speed distribution of motorized vehicles has a major influence on pedestrian safety. There is a clear relationship between the permitted speed and the severity of pedestrian injuries in accidents. The proportion of fatalities among pedestrian casualties increases in step with increasing permitted speed. In other words - speed kills.

Altogether, the main task considering pedestrian safety is to lower the casualty rate for crossing pedestrians. Most of the pedestrian accidents occur in urban areas. Elderly pedestrians, drunk pedestrians and pedestrians in darkness are important target groups in treatments against fatal accidents.

Examples of attained and estimated safety effects for pedestrians of 19 measures are listed in Table 16. Table 16 should be a good estimate of the safety effect for pedestrians in Denmark.

8. English summary

This report is based on analyses and literature studies about pedestrians road safety. The main topics are accident and risk developments for pedestrians, pedestrians road safety compared with other road users, detailed pedestrian accident analyses and also safety effect for pedestrians of several remedial measures. The central results of the report are summarized below:

- The number of pedestrian casualties in Denmark decreased by 26% from 1,552 in 1986 to 1,151 in 1995. Pedestrian casualties decreased by 30% in urban areas, but was unchanged in rural areas in the period 1986 to 1995.
- From 1981 to the years 1993-95 the number of walked km decreased by approximately 20%. Joining accident and travel developments, the casualty rate per walked km has decreased by 8% from 1981 to 1993-95. However the 8% is slightly uncertain.
- The casualty rate per personkm is approximately 8 times higher for walking than travelling in a passenger car and a bit higher per personkm as cycling - according to accident data collected by the police. Per trip the casualty rate for walking is much lower than for both cycling and travelling in a passenger car. Per personhour the casualty rate for cycling is twice as high as for walking and travelling in a passenger car.
- 70-75% of all pedestrian casualties in traffic areas recorded at hospitals are falls with no vehicles involved. If falls is included in the risk assessment, the casualty rate per trip is twice as high for walking as for travelling in a passenger car.
- About 75% of all police reported pedestrian accidents are with crossing pedestrians.
- The largest part of pedestrian casualties is located on urban links. 84% of pedestrian casualties in 1995 occured in urban areas. Casualty rates per walked km are highest in larger cities. Pedestrian accidents are predominant in larger cities.
- High risk groups are elderly pedestrians, drunk pedestrians and pedestrians walking in darkness. Only 21% of pedestrian fatalities involves sober pedestrians, who walked in daylight and was below 75 years of age.
- Some of the special safety problems among elderly pedestrians are accidents with cars going backwards and accidents when bording or alighting the bus. Children aged 5-8 years has a special safety problem when crossing the road near parked cars.
- Tests and assessments by the police of persons involved in injury accidents shows that 12% of the pedestrians has a blood alcohol concentration of 0.8 g/l or higher. This is a high percentage compared to only 4% drunk cyclists and 8% drunk car drivers.
- Even though 80% of the counterparts in police recorded pedestrian accidents are cars, cyclists is a rather big problem. In 10% of the police recorded and 28% of the hospital recorded pedestrian accidents between pedestrians and vehicles the counterpart is a cyclists.
- The average speed and speed distribution of motorized vehicles has a major influence on pedestrians road

safety. Also there is a distinct connexion between permitted speed and the severity of pedestrians injuries in accidents. The share of fatalities among pedestrian casualties increases steadily with increasing permitted speed. In other words - speed kills.

Altogether, the main task considering pedestrians road safety is lowering the casualty rate for crossing pedestrians. Most of pedestrian accidents takes place in urban areas. Elderly pedestrians, drunk pedestrians and pedestrians in darkness are important target groups in treatments against fatal accidents.

Examples of achieved safety effects for pedestrians of 19 remedial measures are listed in table 16. The table is set up on basis of a comprehensive literature study and analyses. Studies of remedial measures which are far from Danish standards has been sorted out. Table 16 should be a good estimate of the safety effect for pedestrians in Denmark. Table 16 is not a key for safety effects for pedestrians, but results from effect studies. The large intervals for safety effects are due to different results in the effect studies.

Some reservations about table 16 should be mentioned. The safety effect is dependent of the -use/behaviour of the remedial measure, the amount of pedestrian and vehicle traffic and also the detailed layout. The safety effect at point oriented measures such as junction improvements, pedestrian crossings and refuges is estimated within 50 metres of the remedial measure.

Table 16 points out that pedestrians road safety can be improved by well-known remedial measures. However some of the measures in table 16 are very widespread in Denmark for instance footways and road lighting.

Remedial measure	**Accident types influenced**	**Achieved/estimated safety effect**
Speed reduction of 0,5-18 km/h[1]	All pedestrian accidents	-17% to 92%[2]
Footway	All pedestrian accidents	Accident reducing[2,3]
Combined foot and bicycle path[4]	All pedestrian accidents	-37%[2]
Pedestrianisation of road	All pedestrian accidents	-82% to -100%[2]
Reorganisation into one-way traffic	All pedestrian accidents	-34% to -62%[2]
Zebra crossing on stretch	Accidents with crossing ped.	+50% to -50%
Zebra crossing at priority junction[5]	Accidents with crossing ped.	+127% to -35%[2]
Footbridge[6]	Accidents with crossing ped.	-85%
Side road pedestrian refuge with kerb	All pedestrian accidents	+50% to -27%[2]
Other pedestrian refuge with kerb	All pedestrian accidents	+27% to -81%
Central reserve - marked or with kerb	Accidents with crossing ped.	-57% to -82%[2]
Guard rail on central reserve or at footway	All pedestrian accidents	-20% to -48%
Signalization of a zebra crossing on link	Accidents with crossing ped.	-20% to -35%[2]
Roundabout	All pedestrian accidents	-46% to -89%
Signalization of a junction	All pedestrian accidents	-0% to -70%
Scramble - exclusive pedestrian signal phase	All pedestrian accidents	-7% to -63%
Road lighting	Pedestrian accidents in dark	

		-35% to -45%[2]
Improved lighting at pedestrian crossing	Pedestrian accidents in dark	-30% to -62%[2]
Reflector, reflective strip	Pedestrian accidents in dark	-89%

Table 16. *Achieved safety effects for pedestrians when implementing remedial measures. A safety effect of -20% stands for a reduction of 20% in numbers of accidents. Notes: 1. Average speed reduction of motorized vehicles by changes in permitted speed, increased traffic control, bump, hump etc. 2. Safety effects based on (among others) Danish studies.; 3. The magnitude of the effect is uncertain. 4. In the before period there was no footway or footpath of any kind. 5. The safety effect of zebra crossings at junctions depends on the location of the zebra to the crossing road. 6. The safety effect of a footbridge (in this study up to 200 m away from bridge) depends heavily on the use.*

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Annex 1

Travel surveys and calculation of risk indicators
"TU" is the Danish abbreviation for "National travel surveys". It is an interview survey, the purpose of which is to describe the personal transport habits of the Danes. TUs enable us to describe, for instance, the mode choice of transport and lengths of trip, and they give certain demographic data.

Travel surveys
Five national travel surveys have been conducted during the years 1975, 1981, 1986, 1993-1994 and 1992-. The latter survey (1992-) is an ongoing survey which is still in progress, although this report has only used the results for the years 1993-1995. There are several methodological differences between the five surveys. These descriptions are based on material from the following sources: Danish Bureau of Statistics (1982a), Ministry of Transport (1992) and Danish Road Directorate (1996). *(1996)*.

TU75 was carried out by AIM. Information on trips undertaken on the previous weekday and weekend (both Saturday and Sunday) were answered in home interviews, by 6,875 persons aged 18 years or over, chosen from 3,928 households, during the month of October. A particular difference between TU75 and the other surveys was that the times and lengths of trips were stated in intervals in TU75. Trip lengths are rounded off to the nearest whole kilometre in the other surveys. Some key information on weekend trips has not been found in TU75.

TU81 was conducted by the Danish Bureau of Statistics and the National Institute of Social Research. In contrast to TU75, only a single, selected person aged 16 years or over was interviewed in each individual household. The information on trips is based on 3,619 interviews. All interviewees were asked for trip information for one weekday and one Saturday or Sunday during the month of October.

TU86 was conducted by the Gallup Institute. TU86 was conducted as home interviews, together with the subsequent returning of a journal of the respondent's travel activities on a specific day. 5/7 of the interviewees were asked for information on weekday trips and 2/7, for information on a Saturday or Sunday in the month of October. In TU86, one randomly-selected person aged 15 years or over, from each individual household, was interviewed at home and provided with a journal. The trip information is based on 2,632 returned journals. The trip information requested in TU86 was designed to be as simple as possible, for which reason time and place criteria were omitted, since the interviewees were to complete the journals themselves. In practice, it is to be supposed that the journal method results in a larger number of trips because the interviewees state stages of a trip as complete trips and, perhaps, "remember" more trips.

TU92- is carried out by the Danish Bureau of Statistics. TU92- is based on telephone interviews conducted throughout the year, with the exception of July, in which the previous day's trips and previous month's journeys exceeding 100 km are recorded. The Danish Bureau of Statistics sends an informative letter to all interviewees prior to the actual interview. TU92- did not start until August. Between 1,200 and 1,500 persons aged from 16 to 74 years are interviewed every month. TU92- differs from the other surveys insofar as it requires a minimum trip length of 300 metres, which means that short trips are not included. The trips of less than 300 metres started to be distributed over mode of transport from May, 1997, which is also the only month for which this data has been processed. 65% of trips of less than 300 metres were made on foot during that month. Calculations show that about 37% of trips made on foot are shorter than 300 metres.

The travel survey of children and the elderly was carried out by the Gallup Institute. The home interviews were conducted in November 1993, and April 1994. A total of 1,003 children aged between 6 and 15 years, and 1,074 elderly aged 75 years and over, were interviewed. The survey did not cover the elderly who were permanently bed-bound, seriously ill or senile or who suffered comparable handicaps. Children and elderly were asked to describe their transport activities on the two days prior to the interviews. In other respects, the travel survey of children and the elderly was conducted in the same manner as TU92-.

No further use has been made of TU75 in this report because of its lack of information on weekend trips. No further use has been made of TU86 due to the use of the journal method and because of calculation errors in accounting trips, etc.

Calculation of risk indicators
The concept of risk expresses the probability of undesired events. In the context of traffic, risk denotes the probability of a traffic accident or of a person becoming a casualty as a result of a traffic accident. Simply expressed:

$$Risiko = \frac{Uheld}{Uheldseksponering}$$

The accident exposure of a group of road users is normally understood as a measure of the frequency with which that group figures in situations that can develop into accidents. Three measures of exposure are used in this report, i.e., person-kilometres, trips, person-hours. The ratio of exposure to the number of casualties is normally designated "own risk", which could, for instance, be the risk of being injured per walking trip

$$Egenrisiko = \frac{Antal\ personskader}{Antal\ gangture}$$

In this report, own risk has been estimated on the basis of accidents recorded by the police and of the national travel surveys (TU) during the period 1993-1995 and the travel survey of children and the elderly 1993-1994. The following contains a more detailed explanation of the estimation of exposure on the basis of TU93-95 and the travel survey of children and the elderly.

Own risk distributed over age intervals
In Chapter 3, own risk is distributed over age intervals and mode of transport (although, as far as age intervals are concerned, linear average of 5 age levels were used to obtain more certain estimates).

A list of interviewees' travel, e.g., for determining national person kilometrage would normally require statistical weighting from the standpoints of sex, age (16-24, 25-64 and 65-74), degree of urbanisation, civil status and type of dwelling. Such weighting was not carried out for TU93-95 as the number of interviews/age interval is large (about 700) and because weighting would be needed for rather large age groups. Instead, we have elected to carry out weighting, which relates the number of interviewees in the individual age intervals to the number of persons in the corresponding age intervals at the national level. This has proved to give a more correct picture of the travel of the individual age intervals, although the person kilometrage of the 16 to 74-year-old remains unchanged, regardless of the weighting strategy applied.

In the case of the travel survey of children and the elderly weighting has been carried out with consideration for sex, age, housing condition, etc., as the number of interviews is relatively small. A weighting was subsequently carried out for the individual age intervals in the same way as in TU93-95, since the first weighting was not sufficiently precise from the standpoint of age distribution.

Own risk, distributed over municipalities, light conditions and urban/rural areas (which are discussed below), has been estimated through the application of weighting, with consideration for sex, age, degree of urbanisation, civil status and condition of housing.

Own risk distributed by municipality
The level of exposure in a municipality has been estimated on the basis of the travel of residents in the relevant municipality. This means that the pedestrian kilometrage, for instance, in the Municipality of Copenhagen, is given by the number of kilometres walked by the citizens of that municipality. As accidents have been accounted by accident location, we find that a degree of uncertainty attaches to the risk in the individual municipality due to commuting, tourism, visitors, etc. We assume that this uncertainty is only modest where pedestrian kilometrage is concerned.

Own risk distributed over light conditions
Information on light conditions prevailing at the time of accidents, i.e., daylight, twilight and darkness, has been added to the data on walking trips, which started at the appropriate times and in the appropriate month. This means that walking kilometrage is distributed over daylight and darkness. Twilight is included under darkness.

Own risk distributed over urban and rural areas

The trips studied in TU93-95 classified the respondents into 5 area-categories. Firstly, the pedestrian kilometrage resulting from "purely walking" trips in which no other mode of transport was used and walking trips in which other modes of transport were used (such as buses or trains), which were undertaken in the area-categories "entirely urban" and "entirely rural", were distributed over the urban and rural areas by interpreting the area-categories in the following manner:

"entirely urban": 100% of walking kilometrage in urban areas
"mostly urban": 75% of walking kilometrage in urban areas, the remainder in rural areas
"about equally urban and rural": 50% of walking kilometrage in urban areas, the remainder in rural areas
"mostly rural": about 25% of walking kilometrage in urban areas, the remainder in rural areas
"entirely rural": 100% of walking kilometrage in rural areas.

This method of calculation gave the result that 73% of walking kilometrage occurred in urban areas.

Secondly, the walking kilometrage resulting from walks in which other modes of transport were used, e.g., bus or train, in area-categories "mostly urban", "about equally urban and rural" and "mostly rural" was divided into 73% in urban areas and 27% in rural areas, which was the result of the classification of the other pedestrian trips..

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