Dutch pedestrian research review

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A review of the main traffic safety research on pedestrians in the Netherlands, 1984-1997

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Contents

1. Introduction

The SWOV Institute for Road Safety Research in the Netherlands has prepared a summary of the main recent pedestrian facility research, development and implementation in the Netherlands.
This research review covers Dutch pedestrian safety research in the period 1984-1997.
Some of the research described is produced jointly with other European countries, under authority of the European Community.

This compilation of the Dutch Research Review was made under authority of The University of North Carolina, Highway Safety Research Centre (HSRC).

2. Summary of pedestrian accident experience

This chapter offers a description of general information concerning the development of traffic safety and mobility of pedestrians in the Netherlands. In addition, two studies concerning pedestrian accident experience will be summarised.
In the first study, by R. Methorst (1993), demographic and social trends are determined by means of a survey. These trends can be used as (part of) an explanation of developments in pedestrian safety. According to the author future developments will not result in an increase in the number of pedestrian accidents, but rather in a limitation of pedestrian mobility and freedom of movement.
The second study, by L.T.B. van Kampen (1991), contains an analysis of injury data of both pedestrians and bicyclists. Results of this analysis are used to determine possible means of reducing the severity of injuries. Protective clothing, safety helmets and car front design are taken into consideration. The subject of car front design is discussed in greater detail in chapter 8, ‘Car front impact requirements’.

The number of pedestrians killed in a traffic accident has decreased strongly in the eighties. This decrease came to an end in the nineties. The year 1996 however, shows a remarkably positive development.
The stagnation in the decrease can hardly be explained by an increase in pedestrian mobility, for this has remained relatively unchanged between 1980 and 1994 (5 - 5.5 billion kilometres per year). In recent years the level of pedestrian mobility is somewhat higher.
Estimates of pedestrian mobility are made by CBS (Statistics Netherlands). According to estimates of the Dutch Pedestrians Association, these official pedestrian mobility estimates are too low. Estimates of the Pedestrians Association indicate a pedestrian mobility 8 billion kilometres per year (for the year 1994).

Year	Pedestrian fatalities	Pedestrian mobility 10^9 km.	Fatal acc. per 10^9 km travelled
1985	187	5.1	37
1986	216	4.9	44
1987	172	5.0	34
1988	201	4.8	42
1989	190	5.0	38
1990	144	5.0	29
1991	144	5.2	28
1992	152	5.2	29
1993	146	5.2	28
1994	123	5.7	22
1995	142	5.6	25
1996	109	5.5	20

Table 1. *Pedestrian fatalities, pedestrian mobility and exposure to risk in traffic.*

Mode of transport	deaths/10^9 km.	hosp. injur./10^9 km.
Car/Van	4	39
Truck/Bus	1	6
Motorbike	59	815
Moped	87	2.537
Bicycle	20	545
Pedestrian	22	291
Total	6	90

Table 2. *Exposure to risk in traffic for different transport modes; average over years 1994, 1995, 1996. Deaths and hospitalised injuries per 10^9 km.*

Pedestrians mainly are killed in accidents with cars. Pedestrian safety therefore is also determined by the mobility of motorised traffic. This mobility of motorised traffic is still growing every year.

Children and elderly pedestrians prove to be the most vulnerable. Nearly 50% of the total number of killed pedestrians is older than 65 years. Their risk, expressed as the number of deaths per kilometre, is also found to be very high: more than 100 deaths per billion kilometres, compared to 27 on average for all age groups (source: Accident Records Registration Division of the Directorate-General of Public Works, 1980-1997).
Next to the elderly, children to the age of 14 are the second most vulnerable age group. The number of children killed in a traffic accident has however decreased more than in other age groups (source: Accident Records Registration Division of the Directorate-General of Public Works, 1980-1997).

It is a known fact that not all traffic accidents are registered. The registration of deaths, however, is known to be complete (or nearly complete). The registration of injury accidents is not. The shown figures are corrected for this under registration.

Age	1990	1991	1992	1993	1994	1995	1996
0 - 5	22	24	25	26	17	25	10
6 - 12	56	45	46	49	48	35	28
13-15	36	29	35	24	39	40	48
16-17	67	80	51	62	41	62	49
18-25	313	305	279	266	283	255	258
26-50	424	377	391	387	421	445	389
51-64	151	149	147	121	160	163	125
> 65	307	272	311	317	289	309	273

Table 3. *Deaths per year for different age groups (for all transport modes).*

2.1. **Methorst (1993)**

In most countries pedestrian mobility and safety are not considered to be important issues. As a result, the national statistical agencies pay little

attention to pedestrian mobility and safety. This in turn leads to under-estimation of present and future pedestrian problems.
Trends in these pedestrian problems are not recognised. Not surprisingly, very few strategies are developed, and no action is undertaken to alleviate the problems.
In this paper the author tries to break through this vicious circle by improving insight in both the present and future position of the pedestrian, in particular the relation between pedestrian mobility and safety.
The Dutch Pedestrians Association (of which the author is a staff member) has carried out a survey on the relevance and representativeness of data regarding pedestrian mobility and safety. Demographic and social trends were identified and used as input for a prognosis of pedestrian mobility and safety.
The study was limited to the Netherlands. Much of what is contained here is likely to be relevant to the USA situation, although the higher proportion of travel by passenger car in the USA should be kept in mind.
Some of the findings are:

- Approximately 3% of the total distance travelled, is travelled by foot.
- Approximately 20% of the total number of trips is done by foot.
- The average citizen in the Netherlands walks about 1,600 times per year and uses a car only 650 times a year.

In the Netherlands walking appears to be safe. According to Statistics Netherlands the number of pedestrians killed or injured in accidents has decreased substantially over the last two decades.
Several studies have shown, however, that the reduction in casualties is largely caused by self-imposed restrictions in mobility by pedestrians.

Due to several factors (travel time budgets, demographic trends, trends in living conditions, educational levels, equal opportunities for women, employment trends and enlargement of scale) car ownership and car use will increase dramatically in the next twenty years. As a result, pedestrians in the future would have less space for care-free, undisturbed and safe walking.
The author stresses the need for governmental interference to prevent this situation from getting out of hand.

2.2. Van Kampen (1991)

Accidents with cyclists and pedestrians tend to be more serious when motorised traffic is involved. In the project ‘Safe bicycle and injury prevention’, therefore, special attention is given to the bicycle, the car front and to the protection of the cyclist.
Part of this study is covered by this report. Research is conducted to answer the question if analysis of registered traffic accidents can lead to judgements of the specific needs of cyclist and pedestrian protection.

Comparing the findings for cyclists and pedestrians, it comes out that both type and severity of the injuries of cyclists and pedestrians show a great deal of similarity. In the group of pedestrians however, the proportion of injury to the legs was significantly greater than in the group of cyclists.
Thirty four percent of the injured pedestrians suffer injuries to the head and skull; 33% of the injured pedestrians suffer injuries to the legs.

Among elderly pedestrians the proportion of injuries to the legs is greater than average, mainly caused by the relatively high proportion of injuries to the upper legs.
Because of the high risk of permanent consequences of these types of injuries, there seems to be an obvious need for measures to protect the legs of pedestrians.
In view of the types of injuries, both cyclists and pedestrians should be protected against injuries to the head/skull. The wearing of safety helmets by cyclists could be a good solution. For pedestrians however, the wearing of a safety helmet does not seem a very obvious measure. Reconstruction of the car front end should provide important contributions to the protection of both cyclists and pedestrians.
The proportion of injuries to the legs for pedestrians is similar to the proportion of injuries to the head/skull. It can therefore be concluded that protection of the legs of pedestrians is important. The wearing of protective clothing is not an obvious measure. Reconstruction of the car front end, especially the bumper and its surroundings is an important measure.

3. Pedestrian crossings

This chapter outlines several studies on pedestrian crossings. Attention is paid to both safety aspects of signalised and unsignalised pedestrian crossings, as well as to innovative measures in order to improve signalised pedestrian crossings. Several studies are mentioned briefly right below, and are fully described thereafter.

The first study (Boot, 1987; see § 3.1) contains an analysis of traffic accidents on signalised and unsignalised crossings in the Netherlands. Results of this analysis are compared with similar data on the safety of Swiss pedestrian crossings. The results show that installation of unsignalised pedestrian crossings does not lead to an improvement of traffic safety. Signalised crossings in situations with high volumes of motorised traffic and pedestrian traffic however, proved to have a positive effect on traffic safety.

The second study (Lange, 1996; see § 3.2) comprises an observational examination of crossing pedestrians. Examined is which factors influence jaywalking at signalised crossings.

Three studies (Levelt, 1994; Janssen & Van der Horst, 1991; Levelt, 1992) concern innovative measures for improvement of signalised crossings. *Pedestrian opinions on the alternative Maastricht crossing* (Levelt, 1994; see § 3.3) covers a survey of pedestrians using the alternative 'Maastricht' crossing is described. Traditional signalised pedestrian crossings in the Netherlands consist of red light (standing man) above a green light (walking man), positioned across the street. Before the green light changes to red it flashes for a short period. In the alternative 'Maastricht' crossing, the same traffic light is positioned on the near side of the crossing instead of the opposite side.
In *An evaluation of 'flashing yellow' at signalised pedestrian crossings* (Janssen & Van der Horst, 1991; see § 3.4), the behaviour of crossing pedestrians using the alternative 'flashing yellow' traffic light is observed. In this type of crossing the red light in the traditional pedestrian light is replaced by a flashing yellow light. Whereas the traditional red light means "forbidden to cross", the flashing yellow light means "there could be conflicting traffic; crossing is at your own risk". In the alternative setting green light always means "no conflicting traffic", which is not always is the case with the traditional pedestrian lights.
The most far reaching alternative is discussed in *The Dutch experiment with Pussycats* (Levelt, 1992; see § 3.5). This study consists of an observation and survey of pedestrians using the new type of pedestrian crossing called 'Pussycats'. This type of crossing can be described as an advanced combination of the two alternative crossings described earlier. The pedestrian display consists of a green light (walking man) and a flashing yellow light, and is positioned on the near side of the crossing (the 'Maastricht' position). Further, waiting pedestrians as well as crossing pedestrians are detected and monitored. These technical improvements make it possible to show the pedestrian green light for short periods, to cancel unused calls, and to adjust the clearance time for slow pedestrians and large groups.

The last study described in this chapter (Carsten et al., 1992; see § 3.6) involves the development of simulation models that represent the movement of pedestrians around a street network and the safety consequences of the various road crossing flows.

3.1. Boot (1987)

Signalised and unsignalised pedestrian crossings usually are realised in order to improve traffic safety.
Examinations of traffic accidents on crossings in the Netherlands, however, show that the installation of unsignalised crossings doesn't lead to an improvement of traffic safety. In some cases the number of accidents is found to be increased after the installation of an unsignalised crossing.

In contradiction with these findings, research in Switzerland showed an improvement of traffic safety after the installation of unsignalised pedestrian crossings. These results can, however, be biased by the fact that only crossings in rural municipalities have been studied, and that only fatal accidents (which are fortunately very rare) have been studied.
One of the positive aspects in the results of the Swiss research of (unsignalised) pedestrian crossings was the concentration of crossing pedestrians at one location. Given the bad crossing discipline of Dutch pedestrians, it can be doubted if these results can be translated to the situation in the Netherlands.

The installation of signalised crossings in the Netherlands, according to the criteria used, however, proved to have a positive effect on traffic safety.
It must be understood that signalised crossings in the Netherlands are only realised when volumes of motorised traffic as well as crossing pedestrians are high.

Recommendations

- Unsignalised crossings: the author stresses that a revision of the legal status of unsignalised pedestrian crossings is needed. At present, pedestrians only have right of way when they are already on the crossing. To reduce both waiting times and dangerous conflicts, pedestrians waiting to cross should also have priority.
  Installation of unsignalised crossings should only be considered if no more than one traffic lane per direction is crossed.
  If traffic speeds exceed 50 km/h, the installation of unsignalised crossings should be advised against.
- Signalised crossings: installation of signalised crossings should only be taken in consideration if volumes of both motorised traffic and pedestrian traffic are high.

3.2. De Lange (1986)

This report describes a method to determine the safety and freedom of movement of pedestrians at crossing places. Research has been carried out at crossing places with high volumes of traffic as well as high volumes of crossing pedestrians.

Fifty three percent of the interviewed pedestrians state that high speeds of traffic approaching the crossing impedes the pedestrians while crossing.

The influence of the length of waiting times at signalised crossings on the number of jaywalkers proved to be smaller than assumed. It therefore can be concluded that reduction of waiting time can only have relatively small effects on the number of jaywalking pedestrians.
The type of destination of the pedestrians was found to have no effect on the chance of crossing on red. Age, however, proved to be a significant influence. The percentage of pedestrians of 65 year and older crossing on red light is significantly smaller than the percentage of younger pedestrians crossing on red. In contrast with younger respondents, pedestrians of 65 year and older don't regard waiting times at signalised crossings as a problem. Furthermore, elderly pedestrians do not judge speeds of approaching traffic impeding. This can be explained by the habit of only crossing on green.

3.3. **Levelt (1994)**

The alternative layout for pedestrian crossings, the 'Maastricht design', in which the light is positioned on the near side of the crossing, is under discussion. One of the arguments against introduction of this alternative is the supposed resistance felt by pedestrians, a resistance which has not been expressed so much through complaints lodged with the road planning authorities, but rather through several polls held amongst pedestrians on the street.

Figure 1. *Maastricht design crossing*.

The CROW[1] working group for pedestrian engineering facilities wished to know if this perceived resistance should be taken into account in the recommendation. The CROW asked the SWOV to conduct a study amongst users of the 'Maastricht' crossing, in order to investigate the presence and if so whether such resistance can be overcome through information campaigns.

[1] CROW: Netherlands Centre for Research and Contract Standardisation in Civil and Traffic Engineering.

The SWOV questioned 200 pedestrians at 29 crossings with the Maastricht design, at nine locations, in two municipalities.
First, people were asked to state the characteristic differences, then their preference was asked and finally a comment about perceived safety was requested. The background to the response in favour of one or other layout was questioned. Subsequently, the opinion about a number of characteristics associated with the new lay out was requested.
Some information regarding possible principal advantages was given to the respondent: time won with a short ‘green’ interval, better visibility for the partially sighted and loss of the fright response amongst elderly when they are confronted by a red light while crossing. Subsequently, the interviewee’s preference and safety assessment was once again requested. In this way, it was attempted to obtain an insight into the nature of possible resistances, and it was studied whether information about the advantages of the new design would be able to alleviate resistance.

The first striking result was that less than half of those interviewed were able to cite the actual main distinguishing characteristics: the change in position of the pedestrian light. Exposure to the system did not influence this response.
The second, most important result was that there did not seem to be great resistance to the new design - on the contrary, 32% preferred this layout, 22% preferred the old layout and 44% demonstrated no preference.
The safety assessment, which is strongly related to preference, did not favour either of the two systems: 27% judged the ‘Maastricht’ layout safer, whereas 29% judged the old layout as safer; 44% demonstrated no preference.
In view of previous study results, these outcomes were not anticipated.
People who had used the crossing for a period of over year, at least once a week, preferred the new system.

The advantages and disadvantages cited by people with preference for one of the two systems were related both to the characteristics specific to the system and to characteristics which can also be found elsewhere. Relevant advantages quoted in particular were that the light is more visible and that it is more suitable for the elderly and the partially sighted.
Further advantages cited included the presence of a push button to request a green light and the presence of a sound signal.
The primary disadvantages mentioned were the lack of a pedestrian light opposite, uncertainty about which point of time the traffic would start to move and inability to see the light turn red, so the pedestrian is unsure whether (s)he needs to hurry.
Those in support of the ‘Maastricht design’ in general cited more advantages than the opponents were able to cite disadvantages.

When asked about general positive characteristics of the new layout, people confirmed in general that they are given sufficient time to cross in this system, that the partially sighted are better able to see the light and that the sound signal clearly indicates that the light has switched to green.
People did not agree that they actually are safer while crossing. With regard to negative characteristics, people reiterated in the main that they have more crossing time with the old system, that they do not know at which moment the traffic will start to move and that they are more inclined to cross on red with the new system. They deny that the traffic starts moving as soon as the sound signal stops and that two systems operating in parallel would be

confusing. The inconsistency in the remarks: “sufficient time to cross” and “more crossing time with the old system” could largely be explained by the fact that these remarks were given by different respondents.
A large number of opinions related to personal preference and the safety assessment.

The information given during the interview and the three abovementioned advantages did not lead to a shift in preference or in the safety assessment. Comparison to previous studies supports the assumption that resistance is primarily seen with a change to the existing situation, while there is less resistance to introduction at locations where the crossing was not yet controlled. It was found that only 35% of the pedestrians cross exclusively on green, and that half of those crossing on red press the request button first.

It is recommended that in the process of assessing the ‘Maastricht design’ the resistance expressed by pedestrians should not be taken into account, and neither should a possible variation in uniformity.
Attention is asked - with regard to the installation and information campaigns - for giving pedestrians the option to request green, for sound signals and for sufficient crossing time, if possible by using detectors for crossing pedestrians. It is again emphasised that unnecessary requests for a green light should be avoided, again through the use of detector systems.

3.4. Janssen & Van der Horst (1991)

The replacement of red by ‘blinking yellow’ has been investigated on six different pedestrian crossings in the city of Delft with the aim of evaluating the effects on pedestrian behaviour.

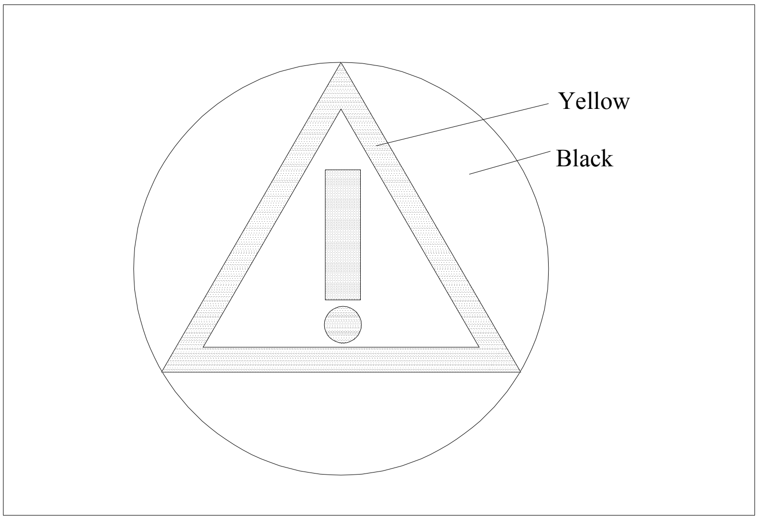

Figure 2. *Flashing yellow pedestrian signal.*

The investigation has been performed in 1989 and 1990 by means of a before/after study. Video registration as well as conflict observations on the spot were applied as investigation methods.
Video results included number of pedestrians crossing in the separate phases of the cycle, as well as gaps accepted or rejected by crossing pedestrians.
A distinction was made between vulnerable pedestrians (children and elderly people) and the remaining group. The main results are as follows:

- The percentage of pedestrians not crossing in the green phase has, on average, been doubled by the introduction of blinking yellow. As a consequence, average waiting times have been reduced.
- The size of the so-called ‘critical gap’ when crossing outside green is not affected by blinking yellow.
- There was no change in the number of conflicts observed when pedestrians crossed outside the green phase after replacement of red by blinking yellow.
- There was no indication that the risk while crossing was in some way specifically increased for vulnerable pedestrians.

It was concluded that comfort at the experimental pedestrian crossing had been improved by the introduction of blinking yellow. It was also concluded that crossing during blinking yellow had by itself not become more dangerous than crossing during the red light previously. However, in so far as crossing outside green will, in principle, be more dangerous than crossing during green, the net results for safety could be negative because of the doubling in the number of people crossing outside during blinking yellow.

Figure 4. *Flashing yellow pedestrian signals.*

Figure 5. *Traditional pedestrian signals (green: walking man).*

The suggestion to replace the red light for pedestrians by blinking yellow would meet the wish of pedestrians not having to wait unnecessarily and make the decision wether to cross themselves.
As a positive side-effect, introduction of blinking yellow would mean an unequivocal relation between the sign of the pedestrian light and the possible arrival of conflicting traffic (the traditional green pedestrian light doesn’t necessarily mean that there isn’t any conflicting traffic).
Furthermore, the existing level of jaywalking would lapse, thus reducing the possible blurring of moral standards in traffic.

Recommendations

1. On midblock crossings the amount of jaywalkers is so low and the waiting times are so short that there seems to be no reason to replace the red light by a blinking yellow light.
2. At crossings of major traffic streams there is a relatively great willingness to wait at red light. The replacement of red by blinking yellow in this situation is unnecessary here too.
3. On crossings of minor traffic streams (parallel with major traffic streams) the willingness to wait at a red light is very low. In situations like this red pedestrian lights could be replaced by blinking yellow lights.

3.5. **Levelt (1992)**

This report is the Dutch part of an international (French, British, Dutch) evaluation study of new pedestrian crossing facilities, merged under the name ‘Pussycats’.

Dutch pedestrian signals consist of a red light (standing man) above a green one (walking man) positioned across the street. Before the green light changes to red, it flashes for a short period. Pedestrians may still start to cross during flashing green. Red means: “if you are on the crossing, move to the kerb as quickly as possible” and otherwise “do not cross”.
In the Netherlands new traffic regulations took effect in 1991. These regulations (RVV) include the introduction of new pedestrian signals, which traffic departments can use to replace the old type. The new alternative pedestrian signals consist of a flashing yellow light above a green one.
The flashing yellow light means: “You may cross at your own risk”. The crossing must be ‘conflict free’ when the light is green.

Pussycats is a new system, characterised by technical improvements, better adapted to the behaviour and needs of pedestrians, particularly those of vulnerable road users.
The pedestrian display has been moved to the near side of the crossing (the Maastricht position), facing the oncoming traffic.
A mat detector replaces the push button, with infrared sensors detecting the presence of pedestrians on the crossing.
These technical improvements make it possible to show the pedestrian green light for short periods, to cancel unused calls, and to adjust the clearance time for slow pedestrians and large groups. Due to the new position of the display, pedestrians cannot see the pedestrian signals while crossing. This could encourage the watching of possible oncoming traffic, and could also prevent pedestrians from becoming concerned or worried about lights turning red when they are halfway over the crossing.

More than 1,000 pedestrians were observed. Their crossing and watching behaviour was noted in relation to the different phases, traffic flows and the presence of other pedestrians.
Two hundred users of the crossing were interviewed, to obtain more information on their understanding of pussycats. They were asked to compare the old crossing with the new one, in terms of safety and convenience.

Figure 6. *Mat detector.*

Figure 7. *Infrared detector.*

Conclusions

1. *Operations and efficiency*: the installation of the mat detector revealed serious problems closely related to the condition of the soil in the west and north of the Netherlands. Peaty soils make installation as prescribed almost impossible. (In more recent studies, however, this problem has been countered by replacing the mat detector by an infrared detector. The detection of waiting pedestrians with an infrared detector proved to be very successful.)

2. *Safety*: the number of crossers during blinking yellow is considerable, but not exceptional by Dutch standards. Fourty six percent of arrivers on blinking yellow also cross on blinking yellow.
   Only one aspect of Pussycats could make a difference. Pussycats is characterised by a very short green phase (only seven seconds). A longer green phase could lead to more arrivers on green and green crossers. Another aspect of the system, the 'wait' lamp, which is not exclusively to pussycats, is also important. The chance of crossing on green increases when people arrive with the 'wait' lamp on.
   As could be expected, increasing the necessary waiting time is related to more red crossing. Contrary to expectations, no relationship was found between the number of vehicles and red crossing.
   Watching, as demonstrated by head movements, is considerable, particularly before crossing. Red crossers are more careful. The Pussycats position of the display, on the side of oncoming traffic, seems to increase watching in the direction of oncoming traffic.
   Most people questioned (87%) said they felt safe while crossing, but Pussycats was not responsible for this. The old system was not found to be safer then Pussycats. Reasons for unsafe feelings were sometimes related to Pussycats, such as the position of the light on the near side.
   It is suggested that information about the operation of the infrared detectors could prevent unsafe feelings relating to the pedestrian display.
   The most important safety advantage for vulnerable road users is the adaption to slow pedestrians.

3. *Convenience*: answers on the function of the mat show insufficient understanding, but the video survey shows that people know how to get a green signal if they intend to cross on green.
   There are no indications that the short green period (seven seconds) bothers the pedestrians. This might be expected, as the audible signal provides an efficient warning.
   The clearance time period extended by the infrared detectors proved to be at least three seconds too short, but hardly any complaints were made about this by the interviewed pedestrians.
   The position of the pedestrian display at the near side of the crossing is regarded as a negative point. Two factors could improve the situation. First, if people know that an infrared detector protects them from passing traffic, the unpleasant feelings linked to not seeing the display turn red could be tempered. Secondly, many people say that they are not used to such a position. Longer experience, covering more sites, could alter the situation.

3.6. **Carsten et al. (1992)**

This report summarises work undertaken as part of the three-year European Community DRIVE programme that began early in 1989. The aim of the project was to examine the feasibility of developing a traffic system that meets the need of vulnerable road users (pedestrians and cyclists) both in terms of travel and safety. There are indications at present that the development of advanced traffic systems such as those envisaged by the DRIVE programme as a whole, may have detrimental effects on pedestrians and cyclists. Most current developments are exclusively directed at the improvement of the safety and efficiency of motorised traffic, and tend to neglect the position of vulnerable road users (VRU’s). As a result, such systems may have negative safety and mobility effects for vulnerable road users which can seriously impair the positive effects on the traffic system as a whole.

Given the nature of the participants in the project, three countries were chosen as the basis for the work, namely the United Kingdom, the Netherlands and Sweden. The initial stage of the work was to examine the problems faced by vulnerable road users in these countries, and also in one urban area within each of the countries, where it is intended that the modelling and experimental work described above would be based. These urban areas were Bradford in the UK, Groningen in the Netherlands and Växjö in Sweden.
One of the two principal tasks of the project was to prepare a traffic model, incorporating vulnerable road users. In addition to performing network assignment, the project would attempt to translate the information on flows of various classes of road users, provided by the model into prediction of conflicts and hence provided some indication of safety effects.
The model requires as inputs real-world data on motor vehicle, cyclist and pedestrian flows as well as on the route choice criteria for the various modes. To calibrate the model, data on behavioural response to modifications in the network are fundamental.
To achieve a wide range of behaviours and environments, data collection was carried out in each of the three countries (the Netherlands, Sweden, UK).
Besides the collection of data, two main types of experiments were carried out. Firstly, two experiments studied the microwave detection of pedestrians (UK, Sweden). Secondly, an observational study was undertaken at an

intersection in Groningen (the Netherlands) in order to test the potential of a system which gives car drivers prior warning when a cyclist approaches an intersection on a parallel bicycle path.

The DRIVE-project has achieved three major pieces of work:

1. It has carried out extensive studies of vulnerable road user behaviour in real world situations to establish the factors underlying route choice and crossing strategies (where to cross). It has also begun the work required to establish the factors underlying crossing behaviour (when to cross).
2. It has carried out diverse experiments using RTI (Road Transport Informatics) detection devices to alter the interaction of vulnerable road users with motorised traffic. Most of these have used the detection devices to alter signal timing in ways that are more responsive to vulnerable road users presence, but the project has also examined the potential for using the detection devices to activate warning signals that alert the driver to the presence of vulnerable road users.
3. It has developed a set of simulation models that represent, albeit in summary form, the movement of pedestrians around a street network and the safety consequences of the various road crossing flows. Another set of simulation models have been built to represent pedal cyclist behaviour at junctions.

4. Traffic calming for pedestrians

The recent stagnation in further reduction of road accidents, insufficient results of existing policies to improve road safety and the rather curative nature of these policies induced the wish to renew and to improve road safety policy in the Netherlands. This new approach is called: ‘a sustainably safe road transport system’.
This system has an infrastructure that is adapted to the limitations of human capacity through proper road design, vehicles fitted with ways to simplify the task of man and constructed to protect the vulnerable human being as effectively as possible, and a road user who is adequately educated, informed and, where necessary, controlled.
As to the infrastructure, the key to arrive at sustainable safety lies in the systematic and consistent application of three safety principles:

- functional use of the road network;
- homogeneous traffic streams; and
- predictability for road users.

Applying all three principles does have a preventative character: to preclude as much as possible the incidence of accidents. A functional use of the road network primarily calls for establishing the intended function of every road. The present multi functionality of roads leads to contradictory design requirements. Therefore, in a sustainably safe infrastructure every road is appointed only one specific function. Pure through roads, pure distributor roads and pure access roads.

In this chapter four studies are reviewed in which the effect of infrastructural measures (with an emphasis on traffic calming) on pedestrian safety are described.
In the first study (Slop & Van Minnen, 1994; see § 4.1) a comparison is made between a ‘sustainably safe’ layout from the perspective of motorised traffic and a ‘sustainably safe’ layout from the perspective of pedestrian and cycle traffic.
The three other studies (see § 4.2 - § 4.4) describe analyses of traffic accidents with pedestrians before and after the construction of infrastructural traffic calming measures.

4.1. **Slop & Van Minnen (1994)**

Up to now, the concept of ‘sustainable road safety’ was mainly elaborated from the perspective of motorised traffic. Policy aims such as more concern for vulnerable road users and promoting bicycle use, calls for proportional attention to pedestrian and bicycle traffic. To that end, this report sets forth the principles of ‘sustainable safety’, elaborated from the perspective of these two categories of road users.
Special attention is paid to the matter of incompatibilities between the perspective of motorised traffic and that of vulnerable road users.
Subsequently, the general considerations are concretised by implementing them, on paper, in a trial area located in the centre of Gouda (the Netherlands).

Comparing the elaborations from the perspective of motorised traffic, bicycle traffic and pedestrians, it comes out that the plans show great correspondence.

The monofunctional road categorisation for motorised traffic, leads to solutions that also proved to be favourable for pedestrians and cyclists:
- reducing the amount of motorised traffic on main roads;
- separation of traffic modes on main roads;
- reducing the amount motorised traffic in city centres, and providing parking space on the outskirts of the city centres;
- replacement of controlled intersections by roundabouts;
- providing tunnels and bridges for cyclists and pedestrians to cross main roads.

Only in a few separate cases the needs of motorised traffic and of pedestrian/bicycle traffic can lead to conflicts of interest. These conflicts usually don't result in negative effects on traffic safety.
The observed correspondence could very well mean that an elaboration in which all traffic modes are taken into consideration, will produce good results.

4.2. **Dijkstra & Bos (1997)**

This report is the Dutch contribution to the study carried out in several European countries as organised by the European Automobile Manufacturers Association.
The report presents accident data on 173 sites in several Dutch cities, before and after small scale measures were introduced. The measures concern several types of pedestrian street crossing facilities and 30 km/h area implementations. Emphasis is given pedestrian safety effects.
In the analysis a distinction is made between location measures (43 sites) and area measures (130 sites). Measures studied were:

Location measures
- narrowing
- narrowing / small bicycle paths
- narrowing / pedestrian waiting strips
- median island
- median island / lanes bending outwards
- median island / axis realignment
- median island / double axis realignment
- median island / bus stop
- junction size reduction
- junction median island
- roundabout

Area measures
- 30 km/h signs only
- road humps only
- road humps / narrowings
- road humps / axis realignments
- road humps / other measures
- road humps / narrowings/ axis realignments
- road humps / narrowings/ other measures
- road humps / axis realignments/ other measures
- road humps / narrowings/ axis realignments/ other measures
- road humps / street closures/ narrowings or axis realignments
- narrowings or other measures (without humps)
- axis realignments / narrowings or other measures (without humps)

Figure 7. *30 km/h zone*.

Conclusions about location measures
With regard to the number of all injury accidents it can be observed that apparently about 50% of the location measures has contributed positively to traffic safety, whereas the other 50% has had a negative safety effect. Only the junction measures (junction size reduction, junction median island, roundabout) seem consistently to generate less accidents. The larger effects, however, mostly are based upon but few data and therefore are not very reliable.
The overall result of the measures is slightly positive for traffic safety.
With respect to pedestrian safety the situation is worse. Except in case of a roundabout, the numbers of both pedestrian involved accidents and pedestrian victims have increased after the measures, albeit effect estimates are rather uncertain because of generally small databases.
The overall result of the measures is anyhow negative for pedestrian safety.

Conclusions about area measures
Accident data show that all measures types were coupled with diminished number of all injury accidents. In one case, however, no effects can be determined. No comparison could be made because there were zero accidents in the before period, due to the short study period. It is striking that even the simple use of 30 km/h signs only, seems to have a considerable positive effect on general safety. The total number of accidents decreased after the introduction of the 30 km/h signs, but the number of pedestrian accidents increased.

Half of the measures had a positive effect on pedestrian safety. In the other half of the cases, pedestrian safety became worse. Nevertheless, the overall safety effect of the area measures is positive for pedestrians, because the positive effects (decrease of accidents) proved to be larger than the negative effects (increase of accidents).

The authors indicate that small numbers and the consequent lack of reliability of the effect estimates were a main problem in this research. Therefore, valid conclusions can at most be drawn at a more overall and general level. In fact, following a more strictly statistical approach, it is obvious that but a very few results may possibly be tested significant at a level of better than 90%.
Within this context, it is noticed that area type measures seem much more effective than location type measures. This is true with respect to all injury accidents as well as pedestrian involved accidents. Also it is true regarding the number of pedestrian victims and the severity of pedestrian injuries. Furthermore, it is found that area wide measures are more safety effective if taken at sites with larger volumes of street crossing pedestrians.

4.3. **Vis & Kaal (1993)**

The 30 km/h zones are supposed to improve road safety and quality of living in areas which predominantly serve a residential function. During a previous study of 15 experimental 30 km/h zones, it was concluded that the total number of accidents after introduction of the measure had dropped by 10 to 15%. With respect to the number of injury accidents, there were indications that the reduction may have amounted to double that figure. Due to the limited scale of the study however, the effects demonstrated a large spread.

In this follow-up study, the effect on the number of injury accidents in a large number of 30 km/h zones was more specifically determined. In this study no special attention is paid to the traffic safety of pedestrians. In earlier studies however, it was concluded that most injury accidents in residential areas concern accidents in which pedestrians and cyclists are involved. A decrease in accidents in residential areas therefore most likely leads to a decrease in the number of injured pedestrians and cyclists.

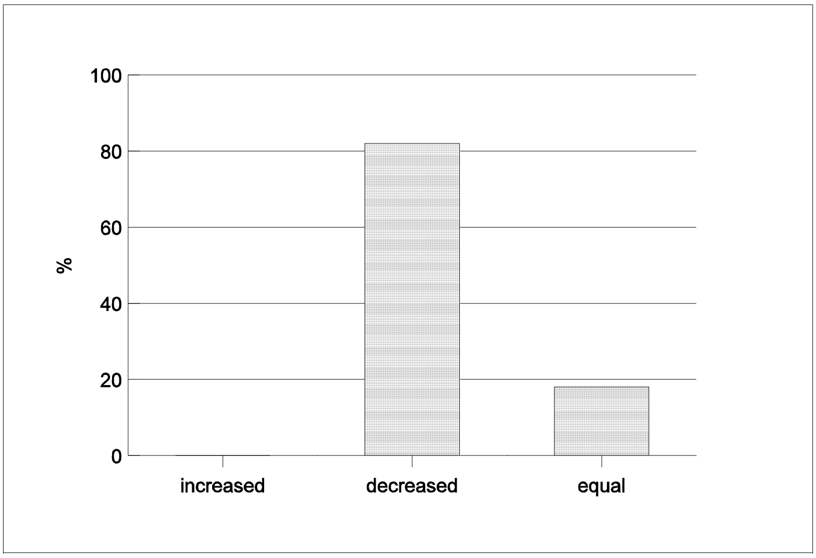

Figure 8. *Changes in speed after reconstruction as 30 km/h zone.*

Of 151 30 km/h zones, 660 injury accidents were recorded: 417 prior to introduction of the measure and 243 during the follow-up period. In order to enable correction of effects which were not associated with the measure

studied, all injury accidents inside the built-up area were collected for the same municipalities over similar periods (control areas).
Following correction based on the trend shown in the control areas, it was determined that the number of injury accidents in the 30 km/h zones had dropped by 22% (±13%).
Again, the effect on the number of injury accidents still demonstrated a large variation. Taking into consideration the (average) results, however, the measure can certainly be considered successful.

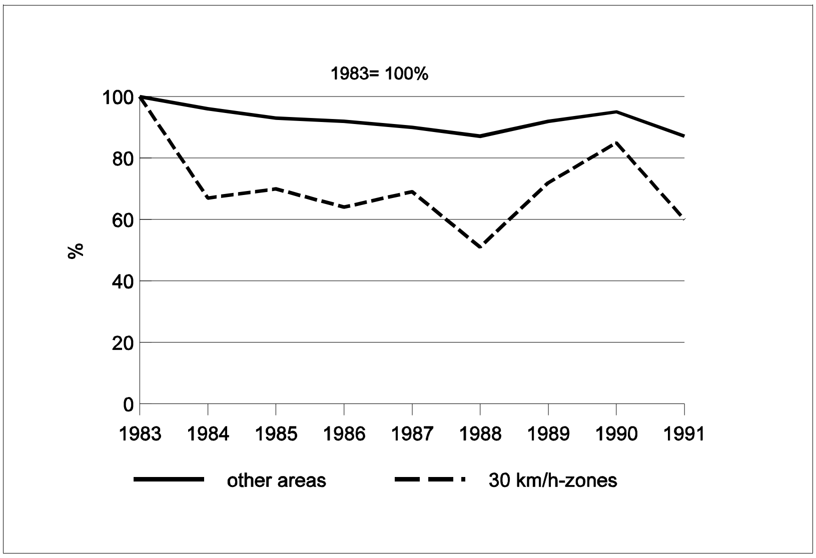

Figure 9. *Development in injury accidents in 30 km/h zones.*

Over half of the surveyed municipalities had not yet commenced work to realise 30 km/h zones, even though the survey held amongst officials from the traffic departments of the municipalities in question demonstrated that a positive attitude prevailed. Intensive stimulation to foster implementation of 30 km/h zones on a broader scale is therefore recommended, while further study into the causes of the reticence shown by many municipalities would be useful.
Furthermore, it is advisable to check if the quality of the applied counter-measures in the 30 km/h are functioning as planned and if this is not the case, to find out why, in order to avoid this in the future.
It has been shown that those areas which are designed as 30 km/h zones tend to carry a lower volume of motorised (through) traffic.

4.4. **Kraay & Dijkstra (1989)**

Analysis of registered accidents in the Netherlands proves that traffic accidents inside built-up areas mainly is a problem of cyclists and pedestrians conflicting with motorised traffic. Further, an important observation is that only 20% of the accidents actually take place in residential streets, and 80% on the main roads. From the point of view of traffic safety, the greatest results in improving safety can therefore be expected from measures on the main roads.
Within residential areas traffic accidents are mostly not concentrated on black-spots, but take place scattered over the entire area.
To improve traffic safety in residential areas in most cases technical measures are needed to influence traffic behaviour in a positive way.

Through traffic must be kept out of residential areas as much as possible. Motorised traffic having its origin or destination within the residential area must adapt its behaviour to the residential character. This implies that driving speeds may not exceed 20-30 km/h.
An area wide approach is, regarding the nature of the problems, far more to be preferred than improving several separate locations. Experiences in the past have shown that a strict differentiation of roads and streets according to their function in the network is a good way of improving traffic safety in residential areas.
Analysis of traffic accidents in redesigned residential areas, as carried out in this study, proves that structural redesign has a positive effect on traffic safety. In residential streets in these redesigned areas the amount of injury accidents per vehicle-kilometre has decreased approximately 70%. On main roads and arteries in these areas a decrease of approximately 20% was found.

5. Children

This chapter discusses a variety of different types of research.
Two studies describe the mobility and freedom of movement of children in relation to traffic safety. In the first (Van der Spek & Noyon, 1993), the authors try to explain the decrease in the number of accidents with children by the supposed decrease in the freedom of movement. The second study (Dutch Pedestrians Association, 1993) consists of school surveys on traffic safety in school zones and in school routes. Results show that the freedom of movement of the children has decreased over the last years. This decrease is explained by the negative judgement of traffic safety on school routes both parents and teachers give. Parents no longer let their children go to school independently, but bring their children themselves.
The study *Driving strategies among younger and older drivers when encountering children* (Lourens et al, 1986) describes observations of the behaviour of car drivers (and deficiencies in that behaviour) in traffic situations in which children are involved.
The study by J. Brinks (1990) describes the behaviour of children in traffic and the deficiencies in that behaviour.
The study *Pedestrian injury prevention* (Molen & Linden, 1987) describes the development of a traffic training programme for children, called 'Crossing the street'.
Next, Douma (1988) evaluates the training programme 'Crossing the street'.

5.1. **Van der Spek & Noyon (1993)**

Over the last twenty years the total number of cars in the Netherlands increased by 85%. A growth from three million cars in 1972 to 5.6 million in 1992.
On the other hand, the total number of fatal and injury accidents in traffic decreased over the same period. The total number of fatal accidents decreased by 60% and the total number of injury accidents decreased by 30%.
For traffic safety the year 1972 is a turning point. Until that year the increase of the number of victims caused by traffic accidents was equal to the growth in traffic volumes. Since 1972 however, the number of victims is decreasing almost every year, whereas the yearly increase in traffic volumes is still going on.
This beautiful result could be caused by technical measures taken over the last 20 years. The life threatening influence of the car tamed by technical measures. The opposite, however, could also be true. Man has adapted himself to the negative influence of the car. Man tamed by the car.
This study tries to explain this paradox; not only by examining the effects of technical measures, but by examining other factors. Examined is whether the freedom of 4-12 year old children has decreased, and to what extent this decrease in freedom of movement can be seen as an explanation of the decrease in the number of traffic injuries.

One generation ago children played outside more often than nowadays. Children were outside their homes most of their time and had more freedom of movement. The games children played by that time, demanded a lot of (public) space.

Nowadays, playing outside is not obvious for a lot of children: 12.6% of the children questioned, almost never played outside, and nearly 30% of the children played outside no more than three times a week.
Playing in the streets is hardly the case anymore. Children nowadays mostly play outside in backyards and squares. In many cases children only play outside under supervision.
When children are playing with friends, 44% of them are brought and taken home by the parents. Therefore their life is more and more organised and their freedom of movement restricted. If children go to clubs or sporting clubs, 65% of them are transported by the parents.
Most children are allowed to play outside only near the house from the age of five or six years. Moving further away from the house is only allowed from the age of eight.

The relation between the freedom of movement of children and the opinion their parents have about traffic safety in the neighbourhood proves to be very clear. If parents give a positive judgement of traffic safety, 55% of the children are allowed to go to school unsupervised. When the parents give a negative judgement of traffic safety in the neighbourhood, only 22% of the children are allowed to go to school unsupervised.
When technical measures are taken to improve traffic safety in the neighbourhood, the judgement of traffic safety by the parents improves, but remains insufficient.

The decrease in traffic accidents with children, while traffic volumes increase, is not very strange. Children don't play outside as much as they used to, mainly because of unsafe traffic. When children go outside to go to school or to play with a friend, they usually are supervised by parents. Traffic hasn't adjusted to the children, but children have adjusted themselves to traffic.

Figure 10. *Reconstructed residential area.*

5.2. Dutch Pedestrians Association (1993)

For several years, the Dutch Pedestrians Association has conducted a school survey (kindergarten and primary school) on traffic safety in school zones and school routes. Here the results of the last survey in 1993 are presented.

Developments in traffic are unfavourable for the traffic safety of school children.
The volumes of motorised traffic have increased by 10% over the last five years. Several schools noticed a deterioration of the behaviour of traffic participants. This increasingly places higher demands on the children in walking to and from school.

Fewer children come to school independently. In 1970, the average age on which as many as 80% of the children came to school independently was six years. In 1993 that age was eight years.
The average distance children had to travel to and from school has increased, leading to an increase in hazardous situations in the school route. Because more and more children are being brought to school by car, traffic volumes increase and from that unsafety decreases. This unsafety causes other people to bring their children to school by car too.

School routes are unsafe. Fourty one percent of the children have to pass busy roads and unsafe locations on the way to school. There seems to be no improvement of the number of traffic accidents on school routes.

Measures to improve the safety of routes to school remain necessary.
At more than 50% of the schools, measures to improve traffic safety have been undertaken. At more than 30% of the schools measures have not yet been taken, though they should have been. Twenty eight percent of the schools claim that undertaken measures proved to be unfavourable for traffic safety.

Parents, schools and government have a shared responsibility. Parents and schools can locate problems, parents can monitor their own behaviour and governments have to take care for safe routes.

5.3. Lourens, Van der Molen & Oude Egberink (1986)

This report presents the results of a study into how drivers *say* they behave, and how they actually behave in traffic situations in which children are involved. An analysis was made of the most important types of encounters in which drivers become involved in accidents with walking, playing or cycling children.
On the basis of accident surveys and psychological theories on information processing, it was assessed by means of a questionnaire concerning their own behaviour in these situations, as well as their expectations about typical child behaviour. Actual behaviour of drivers in these situations was investigated by assessing video recordings of their behaviour in driving a one hour standard track through residential areas.
The most important findings of the study are:
- younger drivers report their own risky driving behaviour more often than older drivers;
- older drivers underestimate their own speed more often than younger drivers;
- female drivers underestimate their own speed more often than male drivers;
- young female drivers proved to score less on the driving task than other drivers;
- there proved to be no relation between driving experience and results in the tests;

- while thinking out loud during the driving test, older drivers prove to give more evaluative judgements, while younger drivers prove to give more detection judgements;
- while thinking out loud during the driving test experienced drivers give more decision judgements than less experienced drivers.

The relatively poor score of female drivers in this study could be caused by a coincidental non-representative construction of the tested group. The authors find it premature to connect any conclusions to these findings.

In the report implications for the contents of mass media campaigns and their evaluation are discussed.

5.4. Brinks (1990)

This study mainly focuses on traffic safety of young cyclists. The results of the study however also apply to the skills of young pedestrians.

In the Netherlands, many cyclists of 12 to 16 years of age are involved in accidents or near accidents. Various studies of basic cycling skills and functional abilities required for safe cycling behaviour indicate that these skills and abilities are for the most part adequately mastered. So, other factors that contribute to (un-)safe cycling behaviour must explain the high accident involvement.
From a cognitive point of view, the knowledge of traffic rules and signs, the knowledge of (normative) rules governing complex manoeuvres and also processing environmental information and linking this information to the proper actions are presumed to contribute to accident involvement. Moreover, attitudinal and motivational issues (including risk acceptance) are pointed out as important factors in accident involvement, particularly in the age group concerned. Our understanding of the way these factors link to accident involvement is increasing. However, little is known about to what extent these factors are mastered in the age group concerned.

In the framework of an evaluation research project concerning the implementation of traffic educational materials, the author extensively investigated the initial situation of 12 to 16 year old children with regard to most of the factors mentioned above.
The investigation shows that there are severe deficiencies with regard to the knowledge of priority rules, particularly when right of way is not indicated by signs or road marks. Also the knowledge of (normative) rules governing complex manoeuvres (such as turning left at an intersection) is inadequate. The same goes for anticipating risks and reacting to these anticipated risks in a safe manner.
With regard to attitudinal issues it is found that attitudes towards safe traffic behaviour are cause for concern. It seems that for 12 to 16 year old children violations of quite dissimilar nature form a sort of conglomerate. Adults (i.e. teachers) on the other hand, appear to differentiate their attitudes with regard to violations in specific situations. This might mean that whereas adults judge their actions on an occasion by occasion basem guided by ‘expert knowledge’, 12 to 16 year old children still lack this cognitive skill.

The consequences that the findings of this study may have for traffic educational objectives and programmes are discussed.

5.5. **Van der Molen & Van der Linden (1987)**

Two major types of measures are dealt with for countering pedestrian injury in residential areas: child pedestrian training and the construction of (residential) yards (in Dutch: 'woonerven').

At the request of the Dutch Ministry of Transport, a child pedestrian training programme for four to six year old children has been developed at the Traffic Research Centre of the University of Groningen.
The major aim of the traffic training programme, is to ensure that the children will cross more safely in the streets where they generally play or walk to kindergarten. It is not, however, the aim of the programme to encourage parents to let their children cross on their own more frequently. All children in this age group do cross some roads in their neighbourhood on their own, however. These are generally very quiet roads without zebra crossing or traffic lights. It is in these very quiet streets however, that the children in this age group become involved in accidents.

On the basis of research the authors concluded that for this age group (four tot six years old) the following road-crossing tasks are the most important:
a. crossing at midblock without visual obstacles;
b. crossing at midblock from between parked cars;
c. crossing at intersections (without visual obstacles).

Task (c) is more important for the five year old, as younger children cross less frequently at intersections. Moreover it is a relatively difficult task for the younger children.

The three road-crossing tasks include a list of actions and decisions which have to be made for a safe completion of the task. These actions and decisions are used as training objectives in the traffic training programme, as described in *Table 4* below.

a. Crossing at midblock, without visual obstacles	**b. Crossing at midblock from between parked cars**	**c. Crossing at intersections**
walk to the kerb at normal speed	walk to the kerb at normal speed	walk to the kerb at normal speed
stop before the kerb	stop before the kerb	stop before the kerb
	at the kerb look inside the parked cars	
	stop at the line of vision	
	stand near the right-hand car	
look left at the kerb	look left at the line of vision	look left at the kerb
		look ahead at the kerb
look right at the kerb	look right at the line of vision	look right at the kerb
		look behind at the kerb
wait if traffic approaches	wait if traffic approaches	wait if traffic approaches
start to look out again when traffic has gone	start to look out again when traffic has gone	start to look out again when traffic has gone
cross at normal speed and right angles	cross at normal speed and right angles	cross at normal speed and right angles

Table 4. *Training objectives for three pedestrian tasks.*

The actual training of the children in the street is done by the parents. Through the school they receive an instruction booklet in which they can read in great detail how to carry out the training in each of the three tasks. In a film at a parents-meeting at school the following training steps are demonstrated:

1. Modelling: the parent demonstrates the desired behaviour to the child.
2. Practise together: parent and child practise the desired behaviour together.
3. Practise alone: the child tries to carry out the desired behaviour under supervision of the parent.
4. Observation and reward: the parent observes the child and reward the child for each behavioural element performed correctly.

The parents should carry out training in each task for about 15 minutes a day for one week.
When the children were tested by test-assistants after the training period, most of them were able to perform almost all behavioural objectives correctly. When tested half a year later this was still the case. It can therefore be concluded that the programme is very successful in establishing the desired behavioural repertoire.
The children were also observed unobtrusively before and after the training period, while playing outside with their friends or walking to kindergarten unsupervised. The improvements in performance were significant. On the other hand however, the observational data show that under normal conditions children do not behave according to their newly acquired abilities.

5.6. **Douma (1988)**

Douma (1988) discusses the results of a study into the effects of the introduction of a traffic education program for young children. In a pilot study an interview method was developed to get a better insight into the way in which young children were involved in accidents.
The amount of accidents with children of the test group proved (luckily) too small, and registration of the accidents too incomplete to use in the evaluation. The evaluation of the education programme therefore is being made by using the results of brief interviews of the parents.
The results show that the education program called ‘Crossing the road’ was effective.
In the study some groups of children proved to be more accident prone than others. The chance of getting involved was found to depend on a set of personal characteristics, backgrounds and exposure. Boys, children of foreign parents and children that were allowed to play longer outside proved to be more accident prone.
Traffic safety measures should be focussed on the accident prone groups of children.

6. Elderly traffic participants

Both studies reviewed in this chapter describe the problems of elderly traffic participants by analysing traffic accident data and mobility data.
The defined problems are then explained by cognitive and physio-functional changes bound up with aging. Possible measures to reduce the problems are described.

6.1. **Van Wolffelaar (1988)**

Van Wolffelaar (1988) reviews the problems of elderly traffic participants as derived from statistical, experimental and gerontological publications. The presented data include changes in mobility, accident involvement and behavioural problems of car drivers, bicyclists and pedestrians. Cognitive and physical changes as a consequence of aging are reviewed and finally some educational objectives for elderly traffic participants are derived from theoretical possibilities of behavioural improvements.

Statistical data indicate that there is a general decrease in mobility among elderly. This applies especially for the distances driven by car, mainly as a consequence of decreased professional activities.
Per distance travelled, however, elderly people are increasingly involved in traffic accidents. Particularly the proportion of victims among bicyclists and pedestrians increases dramatically with age, mainly because of the greater vulnerability due to their unprotected traffic environment.

A striking increase of accident rate is observed in conditions of high traffic complexity and time pressure. This finding is in conformity with results form gerontological studies concerning cognitive and physical functional deteriorations among elderly. These indicate an age-related decrease in functional capacities from which increased problems may be anticipated in complex traffic situations, demanding fast and accurate perceptions, decisions and responses.

First of all, there is a deterioration of sensual perceptions (vision, hearing). Furthermore, the most noticeable characteristic of elderly traffic participants proves to be a slowing down of behavioural performance in both motorial functions (muscles, joints) and psychological functions.
The main issue for eduction of elderly traffic participants, therefore, should be learning to cope adequately with the effects of aging. The main targets of traffic education of elderly traffic participants should be:
1. primarily education: improvement of the knowledge of traffic rules and traffic skills;
2. secondary education: improvement of the knowledge of the effects of aging, learning to cope with loss of function (compensation) and acknowledgement of the need of a good mental and physical condition.

6.2. **Wouters (1991)**

Wouters (1991) provides an overview of recent data on the road safety of elderly people in the Netherlands. Compared with the 30 to 50 year olds, the paper shows that:

- the road hazard magnitude of elderly road users is higher;
- elderly people have more serious accidents;
- elderly people, particularly as pedestrians and cyclists, have a considerably high risk of injury accidents.

The road hazard of elderly people is mainly caused by three interrelated factors. These factors include:

1. Physical vulnerability.
2. The loss of mental and physical function. With growing of age perceptive, cognitive and motorial skills decrease. In traffic this can lead to poor vision in dark and twilight, decreasing of the ability to estimate speed and distance, decrease of hearing. Complex situations in traffic can cause problems in selection of information and decision making. Different decisions can no longer be taken virtually simultaneously, but only successively.
3. A mobility decrease. The decrease in mobility is strongly related to socio-economic factors such as decreasing family-size and retirement. Other factors can be the fear not being able to come along in traffic, fear of own vulnerability in traffic or feeling unsafe in traffic.

The decrease in mobility leads to further deterioration of mental and physical skills and loss of routine. As a result of this, participation in traffic becomes more and more dangerous.
The possibilities for breaking through this vicious circle are as follows:

- Slowing down the loss of mental and physical function of elderly people by either maintaining or improving their traffic skills. This means that they should be stimulated to keep on participating in traffic.
- Other road users should have more consideration for both the possibilities and limitations of elderly people.
- The traffic situations should be modified in such a way that elderly people can participate in traffic in both a satisfactory and safe way.

7. Provisions for disabled pedestrians

The two publications reviewed in this chapter both describe measures and provisions for disabled persons. Neither of the publications describe research on those measures.
The first publication is a manual for infrastructural measures for safe and independent traffic participation by disabled persons.
The second publication describes a device with which pedestrians can double the duration of green light for pedestrians at signalised crossings. This device is used by elderly and disabled pedestrians in the municipality of Enschede.

7.1. **Prikken & Gerretsen (1988)**

One of the aims of the policy of the Ministry of Traffic and Transport is to improve the provisions for a safe and independent traffic participation by disabled persons. In order to make an inventory of complaints and existing problems, a written interview was held among a selection of organisations of handicapped people (Prikken & Gerretsen, 1988).
Complaints of handicapped people mainly concern problems experienced in city centres and shopping centres. Problems that handicapped people encounter can be divided into the following groups:

- route difficult to traverse;
- problems reaching certain destinations;
- accessibility of destinations;
- usability of provisions or destinations.

The necessary bottlenecks which should be inventoried are road sections and streets, crossing places, junctions, roundabouts, squares, shopping areas and traffic restrained residential areas. The manual pays attention to organisational aspects, but also gives technical solutions for problem situations. Traffic safety effects of the given measures are not studied or reported. Research shows that in the bigger cities structural arrangements are made by the organisations of the disabled persons. In smaller cities problems are mostly solved by ad-hoc solutions. The problems are then mostly underestimated and applications are mostly not executed well.

7.2. **Municipality of Enschede (1992)**

In its report, the Municipality of Enschede describes the results of an evaluation of an experiment in the municipality of Enschede with so-called pedestrian transmitters.
The pedestrian transmitter is a device by which pedestrians can double the duration of green for pedestrians at signalised crossings. It also activates a sound signal on the traffic lights, indicating red and green for pedestrians. Moreover, the pedestrian transmitter stops all other directions when the pedestrian light turns green. All directions turn red on green for pedestrians. The pedestrian transmitter can be used by people who need more time to cross than the average pedestrian (elderly, handicapped).

In the experiment in Enschede thirteen signalised intersections were adapted to the use of pedestrian transmitters. This number is being extended after successful completion of the experiment.

Figure 11. *Guidance strip for visually handicapped.*

In the evaluation, users of the pedestrian transmitter and contact persons of homes for the elderly were interviewed.
Results show that more than 50% of the users uses the pedestrian transmitter several times a week. Nearly 70% of the users claims that they would not take the same route if they didn't possess the pedestrian transmitter.
In general, the users of the pedestrian transmitter are very pleased with both the effect and the functioning of the pedestrian transmitter.

8. Car front impact requirements

The three studies described in this chapter discuss two different aspects of car front impact requirements.
The first study (Van Kampen, 1994) concerns a comparison of both costs and benefits of the implementation of car front impact requirements in the Netherlands. The benefits have been calculated by determining the value of average costs of killed and injured victims, combined with the estimated casualties spared by car front impact requirements.
The other two publications relate to the same study (part I and part II).
The publications describe the development of test methods for evaluating pedestrian protection for passenger cars. The main result of the study is the development and calibration of computer models to describe the severity of injuries of pedestrians being hit by a passenger car, under different circumstances and with different car designs.

8.1. Van Kampen (1994)

In the Netherlands the traffic safety of pedestrians and cyclists has been a major concern for many years, though both the annual number of pedestrian casualties and cyclist casualties have decreased during the past 10 to 20 years, as in almost all European countries.
Dutch policy aims at further reducing these numbers. The proposed measure, introducing tests regarding the front end of cars, is strongly supported by the Dutch Ministry of Transport, since it is expected that both pedestrians and cyclists will benefit.
In order to establish a stronger (international) base for this purpose, the Dutch Ministry of Transport has agreed to have SWOV carry out a cost benefit study on the subject, of which the general design should be comparable to similar studies, already carried out by TRRL (UK) and BASt (Germany) in order to compare results.
In the report by Van Kampen (1994), the Dutch cost benefit analysis carried out by SWOV is described.

The scope of the problem is derived from Dutch national accident data.
The annual number of casualties, relevant to the problem of collisions with car front-ends, is at least 6500 (pedestrians and cyclists). Nearly 200 of these casualties were killed, while 1900 were hospitalised. It is certain that the remaining number of other injured (slightly injured) is in reality far greater than the 4400 registered casualties, due to the problem of under-registration.

In another part of the study gross costs pertaining to casualties have been calculated. This resulted in a 1991 value of average costs per fatality of about 900,000 guilders (415,000 ECU's); the costs per hospitalised are about 115,200 guilders (53,000 ECU's); costs per slightly injured are 28,800 guilders (13,300 ECU's).

The expected effectiveness of the proposed measure has been derived from in-depth accident data, following the model used in the BASt-study, mentioned before.

Using this effectiveness data, as well as the cost data and the national accident figures, Dutch benefits of the proposed measure have been calculated, their total number being more than 750 casualties spared (of whom 11 fatalities, 263 hospitalised). In 1991 money value, these annual benefits amount to 24,800,000 ECU's.
These benefits are the result of the compliance of new cars to the proposed measure. Assuming that each year, some 500,000 new cars, complying to the measure, replace the same number of older cars, the cost per new car may be up to 50 ECU's, in order to keep a positive cost/benefit ratio.
In view of extra cost-expectations for new cars, complying to the measure as reported in the TRRL-study, mentioned above, this means that a positive ratio of benefits over costs of 3:1 is feasible.
It is concluded that implementation of the proposed measure will be of great benefit for the Netherlands.

8.2. Janssen & Nieboer (1990) / Janssen, Goudswaard, Versmissen & Van Kampen (1990)

The European Experimental Vehicles Committee has set up a Working Group to assess and develop test methods for evaluating pedestrian protection for passenger cars. The methods are sub-systems tests to the bumper, the bonnet leading edge and the bonnet top.
Test conditions appropriate for vehicle to pedestrian impacts of up to 40 km/h are considered, with adjustments made to allow for the influence of the vehicles frontal shape.
Computer simulations using the MADYMO CVS program are performed by TNO to gain a better understanding of the complex kinematics of a pedestrian accident. The influence of vehicle shape and pedestrian anthropometry is analysed, as well as the influence of vehicle speed, vehicle stiffness and walking position of the pedestrian.
From the 45 basic simulations and 18 additional simulations it was shown that some vehicle parameters considerably influence the pedestrian responses, while some parameters hardly influence the responses.
Furthermore, it was shown that the responses of the 5th percentile female are within the ranges of responses of the 50th percentile male and six-year-old child. These simulations have shown that the selected protection criteria, for instance the bending moment in upper and lower leg and the knee bending angle, are very well able to discriminate between different vehicle shapes and stiffnesses.
Based on these conclusions test conditions are proposed for the sub-systems tests on the bumper, bonnet leading edge and bonnet top.

In most European countries and in the USA the proportion of pedestrian fatalities due to collisions with motor vehicles ranges from about 15% to about 30% of the respective national traffic death toll. Given this fact, it is considered necessary that this problem be attacked by both pre crash (accident prevention) and crash (injury prevention) strategies. This literature review is concerned with the latter strategy.
Both in the USA and in Europe (EC) long term research strategies supported by governments have been followed aiming at legislation in the near future. Practically speaking this means that safety requirements will be established concerning the (sub system) testing of front ends of cars with respect to collisions with pedestrians.
Ample proof exists that such pedestrian safety requirements are feasible for newly developed cars, while there is also proof that considerable benefits are possible through minor changes of current car design.

The European situation differs from the American with respect to accident and vehicle characteristics, but the offer of the USA to make use of their still growing experience, based on their ongoing pedestrian research programme, should be accepted.

One of the grounds for manufacturers opposed against the proposed new requirements is their concern that these may conflict with existing requirements. Most of the examples of this conflict focus on bumper regulations. These existing requirements aim at the reduction of damage and damage repair cost in minor (low speed) collisions.
Evidence has been found that it is indeed difficult to combine the two sets of regulations, especially when all detailed requirements of the current bumper regulations have to be met as well as future pedestrian requirement. Some compromise between the two sets of requirements could therefore be expected. Also ample evidence is found, however, indicating that application of new materials, both lightweight aluminium and various other kinds of energy absorbing material, will solve most of these problems, even without taking away the characteristics of individual car design. Further, evidence has been found indicating that such new designs will improve the outcome of car to car collisions, especially in case of side impacts with regard to the overall damage.
The fears of car manufacturers that occupant safety may be impaired by the new requirements on pedestrian safety, are at least theoretically unfounded. Mass differences between cars and pedestrians as well as the possibilities to make far better use of available crush distances in both current and new car design guarantee that occupant safety will not be impaired.

From the viewpoint of costs and effectiveness the final assessments cannot be made, since almost no real world experience with these types of constructions exist and therefore could not be reported. However, effectiveness estimates based on experimental designs combined with known figures of the population at risk and the cost of medical treatment of injuries as well as the societal costs of fatalities, injured and impaired, point to a positive balance between effectiveness and costs.
It is recommended, however, that both research institutes and car manufacturers stimulated by their respective governments, combine forces and seek for still further improvement of car design. This is absolutely necessary in view of the still existing amount of crash-incompatibility between motor vehicles of the same type and between different types of road users.

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