The effects of 'non-infrastructural' measures to improve the safety of vulnerable road users

A review of international findings, prepared for the OECD Scientific Expert Group "Safety of vulnerable road users"

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Summary

A scientific expert group of the Organisation for Economic Co-operation and Development OECD is currently preparing a report on the safety of vulnerable road users, and focuses on pedestrians and pedal-cyclists. This report reviews the evaluated effects of what can be called 'non-infrastructural' measures to improve the safety of vulnerable road users. It has been written as a contribution to the chapter 'evaluated safety measures' of the OECD report on the safety of vulnerable road users. Many types of 'non-infrastructural' measures to increase the safety of vulnerable road users can be distinguished. Three selected areas are discussed: education and training, measures to enhance visibility and conspicuity, and protective devices for bicyclists (bicycle helmets). Other types of non-infrastructural measures (such as rules and regulations, enforcement, telematics, and improved car designs) are briefly mentioned.

Education is often put forward as an effective preventive measure. However, evaluating precisely the effects of educational programmes is difficult, e.g. as to accident involvement. Examples are presented that illustrate the difficulties in evaluating educational programmes. It appears that the safety effects of Traffic Clubs for children are still inconclusive. Contrary to the many educational programmes available for (young) children, very few intervention programmes for elderly pedestrians and cyclists have actually been implemented (and evaluated).

It appears those retro-reflective markings accentuating the form of the bicycle or a person (pedestrian), and stressing movements of these road users, are the most capable of having these road users recognized as such. The biggest problem is probably not the effectiveness of visibility aids but rather encouraging more widespread use of even the most basic aids in times of darkness. Only (a small) part of bicyclists use their lights, and conspicuity aids for pedestrians are used even less.

The use of bicycle helmets can markedly reduce head injuries among bicyclists. However, in most countries only a small minority of children and adults wear helmets. Compulsory usage - in several states in Australia and the US - of the bicycle helmet leads to substantial increases in helmet use. However, in many countries it appears that such legislation is not feasible - both governments and cycling-organisations are not willing to make helmet use mandatory (e g. Germany, the Netherlands) or await high usage levels before planning to start legislation (e g. UK, Sweden). Therefore, bicycle helmet use must be promoted on a voluntary basis. This is not an easy task, because overall negative attitudes to the usage of helmets exist among (both adult and children) cyclists and among representatives of cycling and road safety organisations.

It is stressed that these measures should not be taken instead of other measures such as infrastructural improvements; they should rather be seen as complement to other measures. Vulnerable road users can protect themselves, make themselves more visible and have (theoretical and practical) knowledge and skills acquired from education and training. However, they should not be solely responsible for their safety.

Contents

Foreword

A scientific expert group of the Organisation for Economic Co-operation and Development OECD is currently preparing a report on the safety of vulnerable road users, and focuses on pedestrians and pedal-cyclists.
The OECD-report will contain information on the characteristics and environment of vulnerable road users, their mobility, accident and fatality figures, accident factors derived from in-depth studies, evaluated safety measures, implementation requirements, and recommendations.
The Institute for Road Safety Research SWOV participated in this scientific expert group of the OECD as representative of the Netherlands. The present report has been written as a contribution to one of the chapters of the OECD report on the safety of vulnerable road users.

1. Introduction

The term 'vulnerable road users' is applied to those, both most at risk in traffic, and generating little risk to other road users. Thus, vulnerable road users are mainly those unprotected by an outside shield, namely pedestrians and two-wheelers, as they sustain a greater risk of injury in any collision against a vehicle and are therefore highly in need of protection against such collisions. Among these, pedestrians and cyclists are those most unlikely to inflict injury on any other road user, while motorized two-wheelers, with heavier machines and higher speeds, may present a danger to others.
The OECD scientific expert group, which is currently preparing a report on the safety of vulnerable road users, therefore focusses on pedestrians and pedal cyclists (OECD, 1996).

In general, two broad groups of safety improving measures can be distinguished. Infrastructural measures include, for example, the design and application of pedestrian crossings or walking areas, and bicycle tracks, routes and networks; a review of this type of safety measures for the benefit of vulnerable road users is reported elsewhere (OECD, 1996, Ch. 6).
This report reviews the evaluated effects of what can be called 'non-infrastructural' measures to improve the safety of vulnerable road users.

Many types of 'non-infrastructural' measures to increase the safety of vulnerable road users can be distinguished. Only three selected areas will be discussed in the present report: education and training (Chapter 2), measures to enhance visibility and conspicuity (Chapter 3), and protective devices for bicyclists (bicycle helmets; Chapter 4).

This selection does not mean that other types of safety measures are not considered important. The topics of conspicuity aids and bicycle helmets were primarily selected, because in recent years many research reports have been published on these measures, most of which has not been reviewed in other OECD reports yet. The topic of education and training has been selected, because traditionally, these are considered important measures to help increase the safety of vulnerable road users. Many reports on this topic have been published in the past two decades. A few recent examples of evaluations of programmes will be presented that are aimed at children and elderly people, either as pedestrians or as cyclists. Other types of non-infrastructural measures (such as rules and regulations, enforcement, telematics, and improved car designs) will briefly be discussed in Chapter 5. Based on the findings presented in this review, the final section of the report summarizes some conclusions and prospective measures (Chapter 6).

The review is mainly based on literature that was available in the SWOV-library when writing this review (April-June 1996). It focuses on evaluation studies in the selected areas. The evaluated effects of safety measures used in these studies include safety effects (e.g. accident reduction), behavioural effects (e.g. usage of safety devices), or effects on attitudes and/or opinions. A literature search was conducted to identify studies on the topic of non-infrastructural measures to improve the safety of vulnerable road users. In addition, documents obtained from members of the OECD RS7 Expert Group on the Safety of Vulnerable Road Users were used. The report is not intended to include an exhaustive review of the literature, but hopes to present a more or less representative overview of international findings.

2. Education, training and publicity

2.1. Introduction

Traditionally, education, training and publicity are considered important measures to help increase the safety of vulnerable road users. Many reports on this topic have been published in the past two decades. Two previous reports by the OECD, namely 'Traffic Safety of Children' (1983) and 'Effectiveness of Road Safety Education Programmes' (1986), have paid extensive attention to the evaluation of education, training and publicity activities aimed at various target groups including pedestrians and bicyclists (see also, OECD 1993). In addition, the report 'Safety of Two-wheelers' (OECD, 1978) has paid some attention to the education and training of bicyclists. More recently, the OECD-report 'Improving Road Safety by Attitude Modification' (1994) reviews some evaluation studies on traffic safety campaigns aimed at children and pedestrians. No attempt has been made to provide a complete review in this chapter of publications dealing with road safety education, training and publicity. Because these reports offer an excellent overview of the topic, the reader is referred to these publications. In this chapter a few recent examples of evaluations of programmes are presented that were aimed at children and elderly people, either as pedestrians or as cyclists. These are examples of research with the explicit aim of evaluating the effectiveness of a particular programme and are not yet covered in the aforementioned OECD-reports.

2.2. Evaluation strategies and criteria for effectiveness[1]

Before presenting some examples of evaluated road safety education programmes aimed at vulnerable road users, it is important to stress that many different types of evaluation can be used to evaluate these programmes. For instance, a distinction can be made between formative evaluation (including process and product evaluation) and summative evaluation. Product evaluation and summative evaluation can resemble each other closely in methods and criteria used. The conceptual difference lies in the purpose; product evaluation serves to provide information for further programme development, whereas summative evaluation provides data based on which a rational decision regarding continuation or implementation of a particular road safety education programme can be made.

Furthermore, the goals and objectives - both educational and teaching objectives - of road safety education, can be defined on many levels: from very general to very specific, and many different criteria can be used to evaluate an educational programme. The appropriate level to be chosen depends on the stage of development of the programme and the decisions that have to be based on the evaluation. In formative evaluation criteria are derived from the programme objectives and can concern cognitive and psychomotor skills, cognitions, traffic knowledge and understanding. Risk

[1] This paragraph is a summary of what is extensively written about elsewhere (OECD, 1983, 1986; Rothengatter, 1986).

perception, attitudes and behaviour can also be used. In summative evaluation the criteria are directly linked to the goal of the road safety education, in principle, accident reduction. Besides accident involvement of the target group, traffic behaviour can be used. On a more general level, exposure to traffic and economic (cost-benefit) criteria can also be taken into account.

Given the many types of evaluations and the many different criteria, it is virtually meaningless to state that a programme is 'effective or ineffective' without specifying on what level the evaluation took place, and which evaluation criteria were used.

In the OECD-report "Traffic safety of children" (1983) seventeen studies concerning the 'effectiveness' of education programmes were discussed. It appeared that the evaluation of the effectiveness of the programmes was measured in terms of either knowledge, in behaviour, or in accident frequencies. The most commonly found evaluation measure in these studies was that of behaviour. Changes in knowledge were assessed in half the studies, while the effects on accident frequency were considered in only four. Perhaps the most significant is the fact that most of the studies looked at only one measure; only two of the investigations examined changes in knowledge, behaviour, and accidents.

2.2.1. *Programmes aimed at young children*

Traffic education is brought forward as an important safety measure for this age group. Many programmes have been evaluated in terms of behaviour of children. Several studies have shown that practical training of children in real traffic improves their traffic behaviour (Roberts, 1980; Michon 1981, Van der Molen, 1983, Rothengatter, 1984; cited in Gregersen & Nolén, 1994; see also OECD, 1986). Theoretical teaching of children has been shown to improve their knowledge, but has a limited effect upon behaviour (Rothengatter, 1981, 1984; Berard-Andersen, 1985; cited in Gregersen & Nolén).
The influence on accident figures is less clear. Doubts exist about the effect of this teaching and training strategy on accident risk, which are based on knowledge from general child psychology. Children have a number of psychological and physiological limitations. They can learn how to behave, but they can never be relied on to use their knowledge when necessary (Vinje, 1981; Rothengatter, 1984). Evaluation studies of teaching and training programs for children are seldom based upon effects on accident risk. There are no guarantees that effects on knowledge or behaviour automatically lead to a reduced accident risk (OECD, 1990). The main reasons that accidents are seldom used lie in methodological problems such as small numbers of accidents or a low degree of experimental control (OECD, 1983, 1986; Rothengatter, 1986).

Recently, Levelt (1994) made an inventory of the methods by which traffic education is taught to very young children (aged less than six).
He concludes that two recent surveys form an exception, in that the evaluation criteria included accident data (Gregersen & Nolén, 1994; Byran-Brown, 1995). Both are related to the work of so-called "Traffic Clubs". These clubs focus on young children and their parents. All children

of a certain age, e.g. at their third anniversary, receive an offer to become members. The membership is free of charge, or they pay a small fee. Members receive an envelope by mail, every half year, including information for their parents, work sheets, puzzles, gifts, etc.

2.2.1.1. Swedish Traffic Club

Gregersen and Nolén (1994) examined the effects of voluntary traffic safety clubs in Sweden. The example illustrates the difficulties encountered in (the interpretation of) evaluations of education programmes; it is also one of the few studies in which accident risk was used as a criterion.

A general aim of the (Swedish) traffic club is to reduce accident risks in traffic for its members. However, no experimental studies of the club have been made so far and it is therefore not known whether the Swedish club has such risk-reducing effects. A non-experimental evaluation of the Norwegian club, showed that members have fewer accidents than nonmembers (Schioldborg, 1974; cited in Gregersen & Nolén, 1994), but since the study is non-experimental, drawing definite conclusions is difficult. For example, it has been demonstrated elsewhere, that parents tend to decrease their children's exposure to traffic as a result of such programmes (Rothengatter, 1985; cited in Gregersen & Nolén). In non-experimental evaluations of the English Tufty Club, no improvements in knowledge or behaviour were shown (Firth, 1973; Antaki et al., 1986; cited in Gregersen & Nolén, 1994). On the other hand, recent evaluations of another Traffic Club in eastern England using a before and after study-design with experimental and control groups, have shown positive effects on road safety knowledge and self-reported behaviour among members (West et al., 1993; Bryan-Brown, 1994).

The primary aim of Gregersen and Nolén's (pilot)study was to investigate whether differences exist between a group of members in a voluntary traffic club and a group of non-members, in terms of accident risk, traffic behaviour, and the safety concern of the parents. The hypothesis of this pilot study was that the accident risk was lower among existing members compared with non-members. The problem of social selection was assumed to work in favour of the members, thus increasing this difference even more. The main purpose of the pilot study was to prepare and test methods, samples, questionnaires etc. to be used in an experimental study later on, in which three groups would be compared: one experimental group with self-selected voluntary members; one with children persuaded to become members; and a control group of non-members.

The evaluation included three questionnaires, sent out at different points in time and which were answered by the parents. The first two questionnaires were identical. These questions covered mainly traffic accidents and exposure. The third questionnaire was more extensive and included more general questions such as background variables, children's general habits in traffic, and parents' attitudes and beliefs about children in traffic. The non-member group consisted of 671 children, the member group of 1,500 children. Response rates were generally high (on average more than 80%).

The results showed that the member and non-member group did not differ in background variables. Regarding exposure, the results show that the members and non-members have been outdoors the same length of time. However, the members have been exposed to traffic environments less than the non-members. Comparing the total traffic accident risk (traffic accidents/100 hours) the members have a significantly higher risk. The total number of traffic accidents reported was 394 for members and 162 for non-members. If the risk is divided into cycling and non-cycling, it is the accident when riding a bicycle that is higher among members. Other accidents, excluding traffic accidents, do not show the same difference.

The parents reported the length of time that the children have spent in traffic environments without the company of a grown-up. The non-members were found to spend a little more time on their own. A difference was also found between the number of children in each group who were given teaching and training. Many members were given theoretical teaching and practical training as pedestrians. No difference was found in practical bicycle training. The results showed that if only those children who are given training are compared, the member child receives less training than the nonmember child. Concerning the use of safety equipment it appeared that the members used bicycle helmets and child restraints in cars more often. There was a considerable difference in helmet usage, but concerning the use of child restraint the difference was small.

The conclusion was that the results show some safety effects of the club, however, not including the most important aspect: traffic accident risk. Gregersen & Nolén (1994) offer some possible hypothetical explanations for these findings. For example, one possible methodological explanation is that the member parents are more likely to report minor accidents. On the other hand, this risk of over reporting accidents among members should then also be expected to lead to a higher proportion of reported other, non-traffic accidents, but this was not so. One explanation for the unexpected results may be that parents in the member group overestimate the effect of the club, which could lead to a higher degree of exposure. However, exposure was lower in the member group. The overestimation of the skills of the children as road users may, however, also lead to a higher degree of risk taking in traffic. It is not necessarily a matter of quantity, but may be a qualitative aspect of exposure. This cannot be evaluated when measuring the number of hours in traffic, as was done in this study. In general, this type of qualitative difference is very difficult to detect in questionnaires. Another possible explanation may be that membership leads to less teaching and training than the children would have had if they had not become members, because the parents shift the responsibility onto the club.
The results may be interpreted this way, since each member child receives less training than a non-member child.
Gregersen & Nolén (1994) stress that since these explanations are hypothetical and not tested in a controlled experiment, great care should be taken in drawing the conclusion that the effect of the club is negative. However, they also state that the probability that there are such great methodological problems in the study that they hide a positive effect is not very high. Thus their most reasonable conclusion is that the club does not have any effect in reducing accident risk.

Because of these results, however, the plan to evaluate the effects of the traffic club in an experimental study was abandoned, since one group would include children who are persuaded to become members. If this would lead to a higher accident risk, which might be the case, such an experiment must be classified as unethical. The practical result of this study has been a revision of the Swedish "Children's Traffic Club", but this has not yet been evaluated.

2.2.1.2. British Traffic Club

Another recent study into the effects of a Traffic Club on accident risk arrived at a more positive conclusion. As a follow-up of studies showing positive effects on knowledge and self-reported behaviour (West et al., 1993; Bryan-Brown, 1994), Bryan-Brown (1995) used accident data to assess the effects of the Traffic Club in eastern England on child casualties. The accident study compared a region with members (50% of all children) with some regions without members. The analysis of the casualty data was designed to reveal differences in the incidence of casualties in the experimental region compared with the incidence in the control region in a before and after period. A total of 11,514 casualty records - 6,191 from the experimental region and 5,323 from the control - were used for the analysis. Various accident types were examined.

A detailed examination found that the number of casualties occurring when the child was masked from the driver's view has fallen in the experimental region compared with the control region since the commencement of the Traffic Club. The average change from the 'before' period (i.e. 1986/87 to 1989/90) to the 'after' period (1990/91 to 1993/94) was approximately 20%. Similar differences were not observed among child casualties who were not masked from the driver's view. This finding is consistent with the behavioural study of the Traffic Club (Bryan-Brown, 1994) which found that fewer Traffic Club members were reported to stop always when told by their carer and more members knew that they should find a safe place before crossing a road. This difference was statistically significant and points to a casualty saving of about 20% in the experimental region compared with the control region for this particular category of accident.

To examine further whether this reduction was a true 'Traffic Club effect' or caused by some other factor, pedestrian casualty data for seven and eight year olds were collected. All these children were too old to be eligible for membership of the Traffic Club and presumably were not influenced by it. The data were analysed using the same method as for the three to six year olds. There was no significant change in 'masked' casualty numbers for this age group, and so it seemed safe to conclude that the effect for the younger children is a genuine Traffic Club effect.

Other reductions in the experimental region when compared with the control region were observed but were not statistically significant. These included a 12% reduction in all casualties from the 'before' period to the 'after' period, which may be the consequence of a car safety campaign, and a 4% reduction in all pedestrian casualties.

The 1993 data show that in Great Britain 1,690 children aged between three and six were injured as they came from behind a masking vehicle. Bryan-Brown (1995) notes that if the 20% saving found in the experimental region were extrapolated across the whole of Great Britain, 338 fewer injuries might have been incurred by child pedestrians aged between three and six. Based on the pilot study findings the British Traffic Clubs have rapidly grown.

2.2.2. *Programmes aimed at older persons*

From road safety studies, it appears that elderly road users are over represented in the fatal and serious injury statistics (see, e.g. OECD, 1996, Ch. 4). This holds in particular for elderly pedestrians and cyclists.
The accident circumstances of the elderly seem to deviate from those of younger road users. The results of accident studies show, for example, that cyclists are (over)involved in accidents inside urban areas, at intersections, and when turning left (see, e.g. Goldenbeld, 1992). Compared with other age groups, the proportion of collisions with cars, trucks and buses are about 25-40% higher for the elderly than for younger cyclists in the Netherlands (SWOV, 1987.) Pedestrians aged 65 or older are, e.g. over represented in crashes during daylight hours, on weekdays, and in winter (see, e.g. Zegeer et al., 1993). Zegeer et al. also found that older pedestrians are over represented in intersection crashes (particularly involving turning vehicles) and in crashes involving wide street crossings. Similar findings have been reported in the Netherlands (SWOV, 1987). A study conducted in Great Britain showed that most pedestrian accidents involving older people occurred in daylight, in fine weather, and in familiar surroundings (Grime, 1987; cited in Carthy et al., 1995).

When the behaviour of elderly cyclists is compared with the behaviour of cyclists of other age groups, it appears that the elderly are more inclined to follow clearly defined rules. At the same time they have more problems when they suddenly have to adapt their behaviour to the actual traffic situation. For example, it appears that at intersections elderly cyclists seem to indicate more often that they intend to change direction, they more often ride at the right side of the road, they look more often in the direction of other traffic which have to give them priority, and they more often look in the same direction more than once. It also appears that elderly cyclists more often exhibit an increased loss of control with regard to steering the bicycle, have difficulties when mounting and dismounting their bicycle, ride more slowly, and react more slowly to complex situations (Van Wolffelaar, 1988). However, in an observational study the behaviour of elderly cyclists at intersections did not substantially differ from the behaviour of younger cyclists (Maring, 1988); the elderly cyclists mainly exhibited a slower mean speed. Elderly pedestrians in particular have problems when crossing a road. From observational studies, however, it appears that the behaviour of elderly pedestrians does not differ markedly from that of younger pedestrians (see, e.g. Wilson & Grayson, 1986, cited in Carthy et al., 1994). Elderly pedestrians tend to exercise more caution in their crossing behaviour, wait longer before crossing a street, and take less notice of other traffic, while crossing a road. In general, they walk significantly slower than younger pedestrians (see, e.g. Van Schagen & Maring, 1991).

Studies into the ageing process show that, as a consequence of ageing, perceptual, cognitive and motor skills deteriorate. For example, visual acuity, peripheral vision, and the so-called useful field of view decrease with age, and distance perception is impaired at low luminance levels. In traffic situations this could lead for instance to difficulty in estimating distance and speed. Furthermore, overall performance on two simultaneous tasks (divided attention) that require motor responses usually shows age-related decrements. In selective attention tasks it is shown that older adults have more difficulty ignoring irrelevant information. Complex situations such as heavy traffic at high speed are more likely to cause problems in the selection of information and in decision making. Decisions are less likely to be taken almost simultaneously and executed in parallel, but rather in sequence. Hearing impairments related to the ageing process occur in 13% of people aged 65 and over. Hearing impairments may cause problems in localising sounds and consequently in ascertaining from which direction a vehicle is approaching. (For more examples, see, e.g. Carthy et al., 1995; Korteling, 1994; Sivak, 1995; Wouters, 1994). In addition, with increasing age, biological processes result in a reduction of resilience to trauma (greater vulnerability). However, a clear relationship of the diminution of functions with the occurrence of traffic accidents is not (yet) demonstrated, and research relating age-related diminutions to pedestrian and cycling behaviour is very scarce.

These phenomena become obvious at about the age of 45, vary greatly from person to person, and become more marked with age. They can partly be compensated for by, for instance, lessening frequent traffic participation, the avoidance of certain traffic situations, or by taking more time to observe situations. Safety improving measures can be taken from a variety of angles. Some measures can be directed at the elderly themselves. Other measures must be directed at the infrastructure and at the other traffic participants. Educational and training programmes designed for the elderly can contribute to the safety of elderly pedestrians and cyclists.

Practice and routine help to slow the loss of function. Elderly people should know how important it is to keep moving, which possibilities there are for them to use safe walking and cycling facilities and how to practice their skills. Traffic education aimed at elderly cyclists can point out ways to apply suitable compensating behaviour and discourage hazardous compensation strategies. For example, traffic education can point out what situations (e.g. T-junctions and intersections controlled by signs) and manoeuvres (left-hand turns) could pose a danger to older cyclists, why these situations are potentially hazardous, what options for compensating behaviour are available (taking another route, stepwise performance of complex tasks, physical training) and what forms of compensating behaviour (relying too much on hearing) are in fact inappropriate (cf. van Wolffelaar, 1988; Goldenbeld, 1992; Wouters, 1994).

Very few intervention programmes for older pedestrians have actually been implemented (and evaluated). Only one example of a (relatively large scale) evaluation study of an education programme specifically designed for elderly pedestrians could be found; this study will be discussed in the next paragraph.

2.2.2.1. Traffic education for the elderly in Japan

In 1993 a 'Promotion program of participation and practical traffic safety education for the elderly' was introduced in Japan (Morifuji, 1995). The programme is characterized by an emphasis on practice and experience in traffic situations (as opposed to a more theoretical approach), the elderly take active part in discussing their own capabilities and limitations. The objective of the programme is that elderly people gain insight in hazardous traffic situations and learn practical skills how to cope with those situations. The programme consists of various 'modules'; for example, an 'outdoor pedestrian course', a practical course of bicycle riding, and a course to prevent nighttime accidents. So far, only the 'outdoor pedestrian course' has been evaluated by means of a questionnaire among the participants of the programme and an accident study.

In 1993 and 1994 the programme was carried out about 670 times in 188 areas in Japan, including cities, ward, towns and small villages, and a total of about 33,000 elderly people participated in the programme.

The number of accidents involving elderly pedestrians in those areas where the programme was carried out was compared with the total number of accidents involving elderly pedestrians in Japan in 1993 and 1994; these numbers were also compared with those of the year before the application of the programme (Morifuji, 1995). The data seem to indicate a decrease in the number of accidents in the areas in which the programme was carried out, whereas such a tendency is less visible in the data for the whole of Japan. However, these differences are not statistically significant, perhaps partly because of the relatively small numbers of accidents in the 'experimental' areas.

A questionnaire survey (2,211 respondents) showed that 90% of the participants evaluated the programme as 'very informative' (Morifuji, 1995). Almost 40% of the respondents thought that the traffic safety course for the elderly is a necessary tool to help prevent accidents involving elderly road users. The results of the survey also show that the participants in particular valued the elements of 'experience in traffic' and the 'practical instruction', which were important characteristics of the programme.

2.3. Conclusions

In dealing with the issue of road safety (for children and also - elderly - adults), the emphasis is generally placed on the training and education of the vulnerable road users themselves rather than on alternative measures such as town planning, or the behaviour of other groups of road users. Education is often put forward as an effective preventive measure. However, evaluating precisely the effects of educational programmes is difficult, e.g. in terms of accident involvement. And when a reduction of casualties is found, there is no clear way of demonstrating if this reduction is attributable to an educational programme or to other possible factors operating at the same time.

The examples presented in § 2.2.1. illustrate the difficulties in evaluating educational programmes, and it appears that the effects of Traffic Clubs across studies are still inconclusive.

Contrary to the many educational programmes available for (young) children, very few intervention programmes for elderly pedestrians and cyclists have actually been carried out (and evaluated). Carthy et al. (1995) note that this is a product perhaps of scarce publicity about the problem, lack of resources and ignorance about empirical evidence on the high pedestrian accident rate. Another explanation may be that although much general knowledge is available, the exact relationship with specific traffic behaviours of elderly pedestrians and cyclists is not clear at all. Such specific knowledge is needed in order to design and implement tangible countermeasures (Hagenzieker, 1996).

One example of an evaluation of an education programme aimed at elderly pedestrians in Japan was presented in this chapter. Although the study does not show an effect of this programme on accident involvement, a questionnaire study showed that the participants of the programme were enthusiastic about it. Especially the practical approach was valued by the participants.

3. Measures to enhance visibility and conspicuity

3.1. Background

Although in general the majority of accidents involving pedestrians and bicyclists occur during daytime (see OECD, 1996, Ch. 4 for an overview of a number of countries), the proportion of these accidents resulting in fatalities and severe injuries seems to be relatively high during nighttime. When pedestrians and bicyclists are compared, it seems that pedestrians are more vulnerable than bicyclists during nighttime: they show the largest share in fatal accidents. For example, Japanese 1993-data show that about 35% of all victims in accidents involving pedestrians fall during nighttime (defined as the hours of the day between 6.00 pm and 6.00 am), whereas almost 70% of the fatalities occur during nighttime. For victims among bicyclists the Japanese data indicate a nighttime-share of 20% and 40% for all victims and fatalities, respectively. The same pattern is observed in a number of other countries (e.g. in France, Finland, UK), although the exact figures and shares are different between countries and also sometimes less pronounced.

It should be realized that 'nighttime' as defined in the accident statistics (usually by time of day) does not necessarily mean 'during darkness'. The number of accidents occurring during darkness will be somewhat lower than the number of accidents during 'nighttime'. For example, Dutch 1995-data show that 21% of the victims among bicyclists and 29% of the victims among pedestrians fall during nighttime, but 'only' 14% and 21%, respectively, during actual darkness (see *Table 1* and *Table 2*). Approximately 3-5% of all victims among bicyclists occurred in accidents at unlit roads during dawn/dusk or darkness. Of all killed pedestrians 15% occurred in accidents at unlit roads, and about 1% of the injured pedestrians.
Similar findings are reported in accident studies conducted in Australia (Triggs et al., 1981; Brindle & Andreassen, 1984, Hoque, 1988; all cited in Cairney, 1992): depending on the type of road (arterial roads, local streets), 9-18% of the bicycle accidents occurred at night.

Bicycle conspicuity has been recognised as a major safety issue for a long time. In particular, nighttime conspicuity has been an issue, more because of the very evident nature of the problem and the high risk associated with nighttime riding, rather than the absolute number of casualties (Cairney, 1992). A similar reasoning can be applied to the issue of pedestrian conspicuity. Taken into account that bicyclists travel much more during daytime than during nighttime, the risk associated with nighttime travel is about four times the risk associated with daytime travel (e.g. Noordzij, 1976). Noordzij also pointed out that there was a higher percentage of rear end accidents involving cyclists on unlit rural roads, suggesting that rear conspicuity was a critical issue.

A hospital based study of cyclist casualties was conducted in the UK, and covered 776 pedal cyclist casualties (Mills, 1989). Detailed information about the circumstances, location, and manoeuvres of all vehicles involved in the accident, together with details of road, weather and lighting conditions were collected by self-completion questionnaires. Injury details were obtained from hospital records. Lack of conspicuity was assessed to have been a contributory factor in 20% of cases where the cyclist was involved in a collision with a motor vehicle or other cyclist on a road or cycle track. The most frequent accident types were where the cyclist was preparing to turn right and was struck from behind by a motor vehicle (rear conspicuity) or where the cyclist was travelling straight over a junction on the major road and was struck by a vehicle emerging from the side road or by an oncoming motor vehicle wanting to turn right across the path of the cyclist (side and frontal conspicuity).

VicRoads (1990; cited in Cairney, 1992) conducted a bicycle-accident study in Victoria, Australia, in which traffic movements were grouped according to their implications for conspicuity. The first grouping consisted of those movements where the car and the bicycle approached from adjacent directions, and accounted for 24% of accidents overall, 28% of accidents in the dawn and dusk period and 22% of night accidents. From this study it therefore appears that - in terms of absolute numbers - frontal conspicuity when approaching from the side would be the most important conspicuity issue. The second grouping consisted of situations where vehicles approached along the same road but in opposite directions, and accounted for 12% of accidents overall, 14% of dawn and dusk accidents, and 9% of night accidents. Direct frontal conspicuity would be the issue here.
The third grouping consisted of accidents where rear conspicuity was the issue, which was the case in 9% of accidents overall, in 10% of dawn and dusk accidents and in 17% of night accidents. It should be noted, however, that only 13% of rear-end accidents occurred at night. So, this type of accident where rear conspicuity is the issue, is relatively over represented at night. The final set of accidents involved vehicles travelling in the same direction, and so may involve frontal, side or rear conspicuity.
This grouping accounted for 8% of accidents overall, 8% of dawn and dusk accidents and 5% of night accidents.

Cairney (1992) remarks that only 6% of these bicycle accidents occurred at night, 32% occurred during dawn or dusk and the remaining 62% during the day, and while this pattern reflects bicycle use, it also points to dawn and dusk conspicuity being a much greater issue than nighttime conspicuity.
He recommends that it would be worth finding out more about the precise timing of accidents in relation to sunset, because the terms 'dawn' and 'dusk' are rather imprecise. Besides a problem of terminology and definition, the actual size of the 'dawn-dusk' problem may also vary from country to country and may differ for victims among bicyclists and pedestrians. In a study by Aylward and O'Connor (1987), the numbers of pedestrian casualties in South Australia in 1985 are presented according to lighting conditions; their data show that 2% of the casualties were injured or killed during the dawn and dusk period, and 26% during nighttime. As *Table 2* shows, in the Netherlands, 2-6% of all victims among bicyclists and pedestrians are associated with the dawn and dusk period.

Lighting and other conspicuity aids are types of countermeasures that might help to reduce the number of accident victims among bicyclists and pedestrians during darkness and to a lesser extent during dawn and dusk.

	Bicycle								Pedestrian							
	Killed		Hospital		Lightly injured		Total Bicycle		Killed		Hospital		Lightly injured		Total Pedestrian	
Time of day	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Daytime (6 am - 6 pm)	207	78%	1927	77%	7161	79%	9295	79%	84	59%	645	70%	1405	71%	2134	70%
Nighttime (6 pm - 6 am)	60	22%	562	23%	1844	20%	2466	21%	58	41%	267	29%	571	29%	896	29%
Unknown	0	0%	4	0%	21	0%	25	0%	0	0%	4	0%	11	1%	15	0%
Total	267	100%	2493	100%	9026	100%	11786	100%	142	100%	916	100%	1987	100%	3045	100%
Source: SWOV																

Table 1. *Numbers (and in brackets %) of victims among bicyclists and pedestrians during daytime and nighttime in the Netherlands in 1995.*

	Bicycle								Pedestrian							
	Killed		Hospital		Lightly injured		Total Bicycle		Killed		Hospital		Lightly injured		Total Pedestrian	
Daylight/ darkness	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Daylight	210	79%	2004	80%	7445	82%	9659	82%	73	51%	677	74%	1543	78%	2293	75%
Dawn/dusk	6	2%	74	3%	265	3%	345	3%	9	6%	21	2%	39	2%	69	2%
Darkness	50	19%	404	16%	1226	14%	1680	14%	60	42%	212	23%	375	19%	647	21%
Unknown	1	0%	11	0%	90	1%	102	1%	0	0%	6	1%	30	2%	36	1%
Total	267	100%	2493	100%	9026	100%	11786	100%	142	100%	916	100%	1987	100%	3045	100%
source: SWOV																

Table 2. *Numbers (and in brackets %) of victims among bicyclists and pedestrians during daylight, dawn/dusk and darkness in the Netherlands in 1995.*

3.2. Detection, conspicuity and recognition

Terms such as detection, conspicuity and visibility are often mentioned almost interchangeably in the literature. For the purpose of clarification, therefore, these concepts will first be discussed in brief (see also Hagenzieker, 1990). Visibility can be defined as a 50% probability of detection. If an object becomes 'more visible', it is generally implied that its detection 'improves' in one way or another, so that the probability of detection becomes increasingly greater; this implies that, usually, an object can be detected at a greater distance, or that observers need less time to decide whether or not an object is present (reaction time). Sometimes 'visibility' means more than simply 'detecting something'. One can detect something among other elements; then, one can speak of conspicuity. Or something may be recognised and identified as 'a bicycle' or 'a pedestrian', for example (whether or not it is situated between other elements). Visibility does not necessarily imply conspicuity; a particular object may be visible between other objects (i.e. be detectable), but may not necessarily be conspicuous. Conspicuity implies that a particular object must 'compete' with other objects to 'attract attention'. It is of course essential that road users 'see' relevant objects, but the detection of 'something' is generally insufficient to allow adequate decisions with regard to behaviour in traffic.

Various researchers (a.o. Hughes and Cole, 1990) have shown that the observer himself exerts significant influence on whether a particular object is noticed. An observer who expects to encounter objects with certain physical characteristics will more readily 'see' them than when he does not expect them (see, e.g. Theeuwes, 1992).

One could argue that the most relevant type of study to investigate the effects of lighting and conspicuity aids would be a study that focuses on recognition of the bicycle (or pedestrian) between other road users and objects, and that varies the task of the observer (not always search for bicycles or pedestrians). Experiments, for example, in which detection is measured, empty backgrounds are used, and in which the subject knows exactly what to look for, will possibly result in too optimistic findings. With full knowledge of the nature of the test, and no need to be concerned with the demands of normal driving the subjects' expectancies are much different than they would be in normal driving. Under test conditions they can focus their attention on the target detection task and are less likely to be distracted by other things that might be going on. Olson (1996) states that "(...) driver expectancy is a key factor in visibility. On average, when an observer knows what is ahead and about where it will be encountered, it will be detected at twice the distance that it will when the observer does not have those advantages" (p. 106).

Accident studies that, for example, distinguish between bicycles that either used or did not use lights or pedestrians that either used or did not use conspicuity aids are very difficult to conduct, because this type of information is usually not present in accident statistics; studies of this type are therefore virtually nonexistent.

3.3. Bicycle lighting: head and tail lights

Evaluation studies of bicycle lighting can be divided into three groups: those focussing on light output measurements, and those measuring detection and/or recognition distances in on-road testing experiments. The latter group of evaluation studies can be considered the most relevant when considering the topic of this chapter. A third group of studies consists of observation surveys to determine the use of bicycle lights.

In general, vehicle lighting is related both how the vehicle is seen by others and how the vehicle illuminates its surroundings. Contrary to motor vehicle head lights, its function is not so much to light its surroundings, allowing the road user to 'see' properly - bicycle head lights are usually too weak to fulfill this function - but to allow the bicyclist to be 'better seen' by others (e.g. Noordzij et al., 1992)[2].

Cairney (1992) conducted visibility tests in which participants in a 'real life' experiment drove round a set circuit, with stationary cyclists at fixed points. These fixed points were selected with regard to light levels, visibility distance, distance from previous site, and other criteria.

[2]Road lighting is a more efficient way to improve visibility for cyclists and pedestrians. Because this report is confined to non-infrastructural measures, the effect of road lighting will not be discussed.

The circuit was arranged along suburban streets, so that measurements took place under real traffic conditions in rather light, nighttime traffic.
The distance from where the driver first saw the cyclist to the cyclist was measured by a device in the car. Head and tail lights, as well as other conspicuity aids, were tested at least two locations with different ambient lighting conditions. Various head and tail lights were tested (a.o. battery head and tail lights, flashing head and tail light, LED tail light, quartz halogen head light). Each configuration was shown to three to twelve observers.
All tail lights tested were seen by 85% of the subjects at a distance of more than 100 m. Stopping sight distances published by Ausroads indicate that a driver travelling at 60 km/h requires a distance of 80 m to stop his vehicle comfortably. Most of the tail lights were visible at distances considerably greater than this. Cairney concludes that a flashing light-emitting diode (LED) device with a wide spread of light was particularly effective, especially against a cluttered background its advantages were notable.
A helmet-mounted flashing light was less conspicuous, having a lower light output and being affected by riding posture. A steady LED unit had higher light output, but was less effective because of its narrow beam. Cairney recommends that regulations should be changed to allow the use of flashing tail-lights. Detection distances for headlights were much shorter than those for tail lights, with 85 percentiles ranging between 40 and 120 m. This was partly due to mistaking the headlights for parking lights on motor vehicles.

3.3.1. *Presence and use of bicycle lights*

In Australia, Morgan et al. (1991) asked observers to count the number of bicycles fitted with lights. All observations were made in daylight and hence the percentage of bicycles with lights would be a minimum value as there is no legal requirement for lights during the day, and many lights are designed to be removable for reasons of security. Adult commuters have the highest proportion of bicycles with lights but even this was very low at 10-12%.

In the UK, (Watts, 1984) conducted an observational survey of more than 2,500 cyclists riding at night in towns. Nine percent of cyclists had no lights at all, 6% had a missing tail light and 6% a missing front light. Of the lamps observed, 21% were judged to be too dim for the conditions, a further 3% were flickering and 9% were off, the percentage of battery powered lights which were off being about double the proportion of dynamo powered lights (11% compared with 6%).

In the Netherlands, a higher proportion of bicyclists use their lights. Observations were made of moving bicycles in darkness to determine the use of head lights from 1985-1988 (Blokpoel, 1989). Each sample consisted of approximately 1,500 to 3,000 bicycles observed at five sites. It appeared that 55-70% of the observed bicycles used their head lights (ambient lighting conditions were < 25 lux).

3.3.2. *Lighting of motorvehicles*

Not only bicycle lighting, but also lighting of motor vehicles could be beneficial for bicyclists and pedestrians, in the sense that bicyclists will more easily or earlier notice motor vehicles when they use their lights during daytime and can take action to avoid accidents. Daytime running lights (DRL) have been discussed primarily in the Scandinavian countries, Canada, and the United States. The regulations covering their use differ from country to country. A positive effect of DRL on accidents involving bicyclists is reported in some studies (OECD, 1990). After three years experience with compulsory DRL in Denmark, no statistically significant effect on the number of accidents involving bicyclists could be demonstrated, although a positive tendency was noted (Hansen, 1995).

3.4. **Reflectors on bicycles**

In the study by Cairney (1992) mentioned earlier, various reflectors were tested as well. Laboratory tests showed that all of the reflectors used in the study were of lower performance than that indicated in the Australian Standard. The rear reflectors were scarcely noticeable at all during the visibility experiments. Spoke reflectors, viewed from the side, did not improve visibility although reflective tyres (wheel circles) increased detection distance considerably.

Since 1 January 1987, side reflection in the form of wheel circles fitted to both wheels has been compulsory for all bicycles in the Netherlands. By accentuating the two wheels characteristic for bicycles it was assumed to make the bicycle more easily recognisable as such when viewed from the side. From this initial date until 1994, the level of compliance was measured (Varkevisser & Vis, 1994). This assessment was carried out by means of observations at bicycle sheds in three types of location: secondary schools, Dutch railway stations (NS), and the Ministry of the Interior (BiZa). Observations, made in February 1994, showed that about 72% of cycles stored in the sheds of secondary schools and about 77% of cycles stored in company bicycle sheds (NS and BiZa) were fitted with side reflectors to both wheels. The illustration shows the figures for the years 1986, 1988, 1993 and 1994. The slight drop in the presence of side reflectors among cycles in school bicycle sheds compared with 1993 relates to the increased number of ATBs (all terrain bikes), a cycle type which is far less often equipped with side reflectors than ordinary bicycles. ATBs represented about 20% of the cycles in school sheds in 1993 and about 26% in 1994. About 90% of the mountain bikes seen lacked side reflectors entirely. These figures were confirmed by data collected in 1994 from several retailers and from the RAI Bicycle Fair: about 80% of ATBs displayed there still did not have the legally prescribed side reflectors.

Varkevisser & Vis recommend that the government, in consultation with industry, should formulate equipment requirements for all cycle types. Any bicycle introduced onto the market should be assessed on the basis of these standards. If it does not satisfy the requirements, it should not be permitted onto the market.

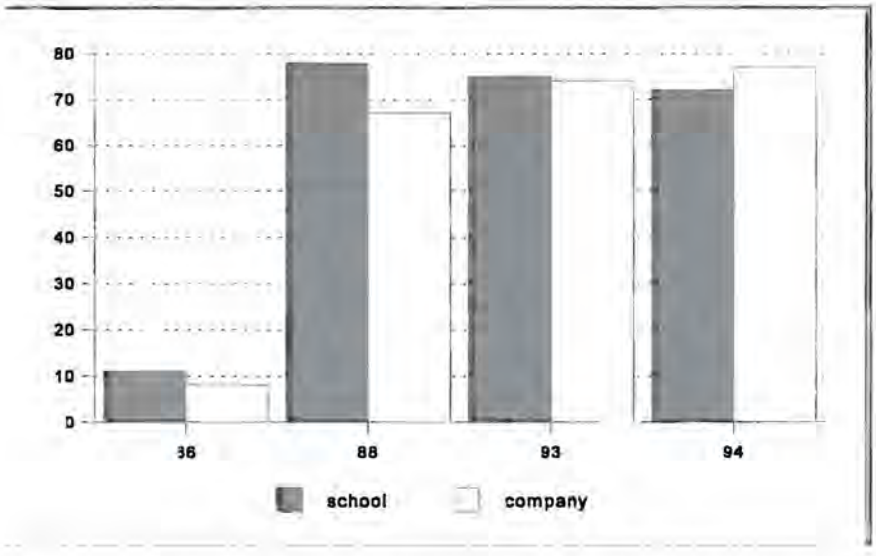

Figure 1. *Percentage of cycles with side reflection 186-1994 in the Netherlands.*

An accident study was carried out in which the four years before the compulsory presence of wheel circles (1983 - 1986) were compared with the two years following this legislation, 1987 and 1988 (Blokpoel, 1990). The results showed a 5% relative reduction of the number of victims among bicyclists at the dawn and dusk period and during darkness as compared to the number of victims during daytime in the period after the law came into effect. As a control, the numbers of victims among pedestrians in the same periods and circumstances were examined; the relative reduction in this group was 1%. Although the decrease of victims among bicyclists was statistically significant when 'before' and 'after' periods were compared as well as when compared with the trend in victims among pedestrians, the assessed effect of side reflectors in the form of wheel circles is rather small. In addition, a complicating factor was that observations have shown that bicyclists equipped with wheel circles also use their headlights more often (70%) than those not equipped with wheel circles (36%). It is unknown in how many cases the wheel circles have played a *conclusive* role in preventing accidents involving bicyclists.

Watts (1984, cited in Cairney, 1992) made observations in the UK, and found that 71% of the bicycles had undamaged rear reflectors, 12% had rear reflectors which were damaged, misaligned or obscured, and 17% had no reflectors. A series of tests was carried out in an off-road situation to determine the detection distance for some lamps and reflectors to aid conspicuity from the rear. The cyclist could be either close to the kerb or near the centre of the 'road'. A pair of headlights to the right of the cyclist simulated head lamp glare from oncoming vehicles and could either be on low beam or full beam. Observers drove towards the cyclist, releasing the accelerator when they first detected the cyclist. The base condition was a cyclist wearing a dark jacket, detectable at only 20 m in the kerb position against full beam headlights and at 64 m in the centre against the low beam. The centre position viewed against low beam always resulted in greatest detection distance, more than 600 m for the best lamp (0.65 cd), just over

500 m for a weaker lamp (0.15 cd), almost 400 m for a very bright reflector (1450 mcd/lux) and just over 200 m for a weaker reflector (214 mcd/lux). All devices gave the shortest detection distance in the kerb position viewed against high beam. These were just more than 100 m for the best lamp and 60 m for the weaker lamp, and just less than 100 m and just more than 50 m for the reflectors. Further tests were carried out with the cyclist in the kerb position viewed against low beam. A combination rear lamp and small reflector gave a *detection* distance of 650 m and a *recognition* distance of only 54 m. A flashing amber beacon gave a slightly lower detection distance and a similar recognition distance. Although a very bright reflective jacket (10,000 mcd/lux) and pedal reflectors had much shorter detection distances (280 and 180 m respectively), they were of benefit in delineating the object as a cyclist and had relatively long recognition distances (100 and 125 m respectively). Reflective cross straps and a reflectorised spacer were less effective on both measures.

3.5. Fluorescent and retro reflective materials for pedestrians and cyclists

A popular approach to increasing nighttime visibility of pedestrians has been to recommend the use of light coloured clothes and retro reflective materials. These materials can be highly visible from distances far greater than required stopping distances for vehicles travelling at high speed (Aylward & O'Connor, 1987). Many studies have shown that retro reflective markings increase the visibility distance of pedestrians at night (e.g. Rumar, 1976, cited in Luoma et al., 1995). Sufficient reflectivity, contrast, area, and durability of retro reflective markings have been considered the key variables affecting pedestrian visibility. While providing a substantial improvement in the distance at which a pedestrian is *detected*, good retro reflectors, as such, may not ensure that a driver *recognizes* the bright target as a person.

In the earlier mentioned study by Cairney (1992) reflective garments were tested as well. These were generally seen by 85% of participants at distances of 100 m or more. However, their conspicuity varied quite markedly with the posture of the rider. In all cases, the cyclist had a battery tail-light and a reflector, the Australian legal minimum treatment for bicycles at night. The reflective garment was generally not visible until well after the tail-light had been seen. Their most appropriate function seems to be as a supplement to lighting, especially as an aid to recognition, according to Cairney.

In the US, Blomberg et al. (1984, cited in Cairney, 1992) studied several conspicuity aids for pedestrians and cyclists on the closed road system of an army camp with no other traffic. Stationary bicyclists were viewed by observers. Subjects were required to indicate when they thought they first saw something of interest, and then to indicate when they could recognise what they saw as a 'cyclist' or 'jogger'. Both distances were recorded as detection and recognition data. The baseline bicycle condition was a standard red oblong reflector mounted just under the seat, together with amber pedal reflectors. To this were added reflective strips to the cranks, or a battery-powered lamp which was strapped to an ankle, or a large fluorescent panel with a retro reflective border, together with retro reflective ankle bands. The table below shows the basic results (taken from Cairney, 1992, adapted from Blomberg et al., 1984).

	Detection		Recognition		Visibility Index	
	Mean	SD	Mean	SD	Mean	SD
Base bike	260	83	134	52	181	56
Spokes and crank	255	90	114	48	166	53
Leg lamp	397	109	147	62	232	56
Fanny bumper*	292	102	140	39	201	52
Note: these data have been converted from feet, rounded to the nearest meter. Visibility Index is a measure of visibility which takes into account both visibility and detection distances, derived by multiplying detection by recognistion then finding the square root. * the "fanny bumper" is a large triangular panel of reflective sheeting.						

Table 3. *Results of a test of conspicuity aids for pedestrians and cyclists on a closed road system of an army camp with no other traffic.*

Blomberg et al. (1986; cited in Luoma et al., 1995) compared the detection and recognition distances of five different pedestrian targets in nighttime driving. They found that flash lights produced the longest detection distance (420m), followed by retro reflective markings called rings, i.e. retro reflective bands on the head, waist, wrist, and ankles (232 m), a jogging vest (227 m), dangle tags (162 m), and a base line pedestrian wearing a new white T-shirt (68m). However, the mean distances for recognition were 96, 133, 98, 44, and 32 m, respectively. The results show that white clothing was not a sufficient conspicuity for pedestrians. The authors suggest that 'anthropometric' treatments, i.e. those which match the shape or emphasise the movement pattern of the human body, may have advantages. The results also show that locations of retro reflective markings are likely to be important.

Owens et al. (1994, cited in Luoma et al., 1995) conducted two simulation experiments to evaluate potential benefits of different retro reflective markings for nighttime pedestrian visibility. Of particular interest in that study was the evaluation of the so-called biological motion or biomotion (Johansson, 1975). Specifically, the main question was whether the markings of all the major joints would create a biological motion phenomenon whereby the recognition of moving persons is improved in comparison to having retro reflectors on other locations of the body. Subjects viewed video recordings of a jogger wearing four different retro reflective markings, and their task was to respond as quickly as possible when seeing a jogger. The results showed that performance was better with markings of the limbs than of the torso. Furthermore, when a secondary task was included, the authors concluded that performance was better for markings that incorporated biological motion than for a vest or for arbitrarily positioned stripes on the limbs.

As a follow-up of Owen et al.'s (1994) study, Luoma et al. (1995) conducted a field experiment in which the subjects' task was to press a response button whenever he or she recognized a pedestrian on or alongside the road, while in a car with low-beam lamps on driven at a constant speed on a dark road. Various retro reflector configurations were tested.
The subjects did not know the location of targets in advance. The results showed that the mean recognition distance was 40 m when there were no

retro reflectors, 96 for torso reflectors, 156 m for wrist and ankle reflectors, and 169 m for reflectors on major joints when a pedestrian was approaching the vehicle in which the subject was seated. When a pedestrian was crossing the road, the corresponding recognition distances were 35, 136, 241, and 249 m, respectively. Older subjects needed shorter distances to recognize the pedestrian. This difference may be partly caused by the decreased visual acuity of older people, as well as to their slower information processing. In addition, Luoma et al. assume that older subjects preferred to get more information to decide whether a given target is a pedestrian. The main implication of this study is that retro reflective markings on the limbs, in comparison to those on the torso, significantly increase (by about 60 to 80%) the nighttime recognition distance of pedestrians, thereby confirming the results of Owen et al. (1994). However, the data were inconclusive about the differential effect of the biomotion/major joints configuration and other configurations on the limbs on recognition distance. Luoma et al. remark that retro reflectors on the wrists and ankles are anyhow more practical than on the major joints. Temporary stripes that are frequently used in Scandinavia, for example, are relatively convenient to attach to wrists and ankles, but not to all major joints.

Shinar (1985; cited in Aylward & O'Connor, 1987) conducted a study comparing the detection distance of pedestrians wearing retro reflective tags with that of pedestrians without such tags for motorists approaching them. He found that there was no difference in the pedestrian detection distances although the actual tag itself could be detected much earlier than the pedestrian wearing it. However, because the tag was not associated with pedestrians by the motorists, they did not serve to help pedestrian detection. Shinar followed up this study with an examination of drivers' expectancy in relation to pedestrian retro reflective tags, and found that the tags were only useful when the driver was cued as to their association with a pedestrian. Countermeasures related to nighttime conspicuity therefore must focus not only on employing some means by which a pedestrian may be *seen*, but also that what is seen by the motorist is *recognisable* as a pedestrian.

In contrast to the findings related to visibility, the empirical evidence relating conspicuity of special retro reflective markings to accident rates is not conclusive. Olson & Post's (1977; cited in Aylward & O'Connor, 1987) review of studies on retro reflective license plates for example indicated only very small effects of retro reflection on accident reduction. In the Netherlands, in a study investigating the effect of reflective markings on trucks, it was concluded that these are unlikely to have been of influence to a reduction in accidents involving trucks (Noordzij & Tromp, 1991).

In Australia Morgan et al. (1991) asked observers to count cyclists who were seen displaying a flag, a reflective vest, reflective strips or any other item that could be regarded as an aid to visibility at night. Adult commuters in Melbourne showed the highest rate of 10.7%, followed by 4.8% of cyclists at primary school sites in country centres. Bicyclists at recreational sites and at secondary school sites showed the lowest rates (0.2 - 1.9%).

Of regular cyclists in Western Australia, 2% reported using a reflective garment or bag, 24% reported wearing white of brightly coloured clothing, and 3% reported wearing reflective tape bands (Cairney, 1992).

In Australia, the 'Older pedestrian demonstration project' included a campaign concentrating on the provision of reflective material to pedestrians. A telephone survey was conducted to assess the effectiveness of the 'Wear something reflective' campaign approximately twelve months after the campaign began. Of the 230 calls answered, 27.8% had seen pedestrians wearing reflective material, 26.9% thought that this made the pedestrian more easily seen and 95.2% of the respondents thought that all pedestrians should wear a reflective item at night (O'Neill, 1992). It is difficult to determine whether usage of these materials have increased as a result of the campaign, since no baseline data were available.

In some parts of Sweden peaked caps of highly conspicuous, fluorescent colours have been given to all pupils when they begin school at the age of seven. The main purpose of this undertaking was to make car drivers more aware of the new child pedestrians. The possibility that the caps might give the children a false, or exaggerated, feeling of security, and the behaviour of car drivers in front of children, with and without caps, at pedestrian crossings were investigated. Indications of a false feeling of security were found during interviews in classes, in which the children had been given caps the year before. A closer analysis revealed that this rather indicated some deficiencies in the introduction of the caps. The study of car driver behaviour seems to show that at least at some locations the caps contribute to a somewhat lowered approach speed to the crossing. The caps also seem to make the drivers observe the children significantly better (Dahlstedt, 1995).

3.6. Conclusions

Cairney (1992) concluded from a literature review into lighting and conspicuity aids for bicycles that reflectors and reflective clothing are certainly capable of increasing the distance at which a cyclist can be detected, but are much less effective than a light source. They have a useful role to play in assisting recognition of the cyclist, and in ensuring that motor vehicles adopt a more comfortable clearance when overtaking cyclists. White clothing was shown to be ineffective. Cairney cites Boyd (1986) who regards wheel reflectors as useless. On the other hand, one study attempting to determine the safety effect of reflective wheel circles on tyres reports a small reduction of accident victims among bicyclists after these became mandatory in the Netherlands (Blokpoel, 1990).

Cairney (1992) furthermore concludes that dynamo sets suffer from a number of problems. They are not lit while the bicycle is stationary, they are inefficient, and may blow the remaining lamp if the front or rear lamp should fail. From the literature it appears that flashing lights are more conspicuous than steady lights with the same light output.

Aylward & O'Connor (1987) conclude that from the available evidence, effective countermeasures in the area of pedestrian conspicuity are difficult to envisage. Widespread use of cheap, detachable retro reflective tags, standardised and sufficiently distinguishable so as to be associated with pedestrians may be beneficial to pedestrian safety. However, one should also be aware of potential negative side effects of conspicuity aids.
A Swedish study on the advantages and disadvantages of fluorescent caps

for child pedestrians points at the possibility that such devices might elicit a false, or exaggerated, feeling of security (Dahlstedt, 1995).

From the experiments reviewed in this chapter it appears that retro reflective markings accentuating the form of the bicycle or a person (pedestrian), and stressing movements of these road users, are the most capable of having these road users recognized as such. One should not rely on detection distances, because these are much longer than recognition distances, and usually lead to too optimistic findings regarding the conspicuity of materials. Furthermore, expectations are very important factors in visibility. On average, when an observer knows what is ahead and about where it will be encountered, it will be detected at twice the distance that it will when the observer does not have those advantages. Conspicuity aids alone are not sufficient to secure recognition of vulnerable road users; other (infrastructural) measures should indicate to the drivers of motor vehicles that vulnerable road users could be expected on certain roads (e.g. the presence of bicycle lanes or pedestrian paths can set such expectations).

The biggest problem is probably not the effectiveness of visibility aids but rather encouraging more widespread use of even the most basic aids in times of darkness. As was illustrated above only (a small) part of bicyclists use their lights and conspicuity aids for pedestrians appear to be used even less.
Increasing the use of lights appears hard. A program to encourage light use by bicycles in a New Zealand city was not successful (Ferguson & Blampied, 1991). They report the effects of three different techniques to encourage use of bicycle lights at night. The first was prompting first by means of posters alone, then supplemented by leaflet drops, and some TV and radio support. The second was an incentive competition, where free inspections of bicycles were offered, cyclists having satisfactory lights being entered in a prize draw. The third was to provide feedback in a form that had previously been shown to be effective in reducing speeding. All three programs were basically ineffective in increasing light use. Also in the Netherlands only part of the bicyclists use their lights (although it is compulsory), and their state of maintenance is generally poor. During a campaign in Amsterdam the two main offences by bicyclists were riding through red lights and the absence of adequate cycle lights, each accounting for almost 50% of the total amount of offences (Twisk, 1993). As for cycle lights, the police activities were strongly preventive in character. Fines were dropped if cyclists could show within one week after being stopped that they had actually repaired their lights. Although not systematically observed, the impression was that this approach was somewhat successful in the sense that cyclists were more often using their lights after the campaign ended.

4. Protective devices: bicycle helmets

4.1. Background

Cyclists are more likely to have an accident than other road users and they will sustain a greater proportion of head injuries than other road users. In a literature review Royles (1994) states that many published papers report that at least two-thirds of the cyclists killed in accidents had head injury which either contributed to or resulted in the death of the cyclist.

For example, 84% of the Australian cyclists fatally injured in 1980 had head injury (Dorsch et al., 1984; cited in Royles, 1994), Levy (1987; in Royles, 1994) reported that two-thirds of the cyclist accident deaths in New York State were due to head traumas, in three Finnish provinces 71% of the bicycle accident victims between 1982 and 1988 had head injury diagnosed as the principal cause of death (Olkkonen, 1993) and in Canada, Cushman et al. (1992) reported that head injuries were the reason for 70-80% of cyclist deaths and long term disability. Of the 300 cyclists killed on the road in the UK every year, just over half dies because of a head injury and 29% received injury to the cranium, the area of the head protected by a helmet (Mills, 1989).

In the Netherlands (Goldenbeld & Wittink, 1993), according to the records of the principal diagnosis for hospital admission following a traffic accident, each year more than 2,300 cyclists suffer head or brain injury; every year about 1,000 young cyclists (0-19 years of age) sustain a head or brain injury during a traffic accident; and for cycle victims aged 0-19, the proportion with head or brain injury represents about 50% of all hospitalised road accident victims. Head or brain injuries sustained by bicyclists are considerably more often the result of unilateral accidents, rather than the result of a collision with a motor vehicle (Goldenbeld & Wittink, 1993; in Denmark and UK similar accident figures are reported, Flensted-Jensen, 1991; PACTS, 1992).

4.2. The effect of bicycle helmets in reducing head injury

In a widely quoted article by Thompson et al. (1989), who carried out a case-control study in hospitals in Seattle, it was concluded that cyclists who do not wear a helmet have a 6.6 times greater probability of sustaining a head injury and are 8.3 times more likely to suffer brain injury than cyclists who do wear a helmet. According to these data, therefore, a reduction by a factor of eight in the annual number of cyclist victims with brain injury could be achieved if all cyclists were to wear a helmet. Dorsch et al. (1987) carried out a postal survey and estimated from reported helmet use and head injuries that the risk of death from head injury is 3-10 times greater for unhelmeted relative to helmeted bicyclists, depending on the helmet type.

In Denmark, Bernhoft et al. (1993) concluded from an in-depth analysis of fatal accidents involving cyclists (n = 88), that about one third of these accidents involving children, adults and elderly cyclists, the cause of death was exclusively head injuries (especially among children) or related to serious head injuries (among elderly). These authors conclude that in some of these accidents the usage of a bicycle helmet might probably have reduced the severity of the injury, and thus avoided a fatality.

Royles (1994) reviews a number of studies that address the issue of how many bicycle related deaths and head injuries could be prevented if cyclists wore helmets. For instance, Sacks et al. (1991; see also Brewer et al., 1995) estimated that, from 1984 to 1988, 2,500 of the 2,985 deaths of which head injury was the principal cause and 757,000 of the 905,752 head injuries in the US could have been avoided if all cyclists had been wearing helmets. In Sweden, Lind & Wollin (1986; in Royles, 1994) carried out a questionnaire survey and concluded that more than 70% of the accident victims - from 117 accidents that had the head recorded as the main site of injury - would have benefitted from the use of a helmet. Olkkonen (1993) investigated the injury severity of bicycle accident victims in three Finnish provinces from 1982 to 1988; it was estimated that almost 50% of the fatal injuries (of 200 victims) could have been prevented if a helmet had been worn. Wasserman & Buccini (1990; in Royles, 1994) analysed 191 questionnaires from recreational cyclists who reported having fallen and struck their heads in a cycling mishap. Fifty seven percent were wearing helmets. The helmet wearing reported significantly fewer skull fractures and fewer facial soft tissue injuries than the non-wearers.

Although each of the aforementioned studies may be criticized on some methodological grounds, the overall evidence of bicycle helmets reducing head injury is still quite convincing.

4.3. Stimulating the use of bicycle helmets

Goldenbeld & Wittink (1993) and Royles (1994) describe various strategies to increase helmet wearing by bicyclists in a number of countries.
In Australia, the US, Sweden, Denmark, the UK, the Netherlands and Germany the bicycle helmet was introduced with varying levels of success.

4.3.1. *Compulsory usage*

Australia has made the greatest effort to increase the use of bicycle helmets. On 1 July 1990, the legislation requiring wearing of an approved bicycle helmet by all pedal cyclists came into effect in the state of Victoria. Victoria was the first state in the world to introduce such a requirement. Later, the use of bicycle helmets also became compulsory in the states of New South Wales and Western Australia.

Vulcan et al. (1991) describe the historical background and the results of the legislation in Victoria. In 1977 the Australian standard for bicycle helmets was published, and in 1981 the first helmet was certified as meeting this standard. From then on many activities to promote helmet use took place, including education, publicity, support by professional and interested organisations, bulk purchase schemes and helmet rebates. From 1983 the Education Department required that helmets must be worn when participating in all school activities, including 'Bike-Ed' - a cycling skills and proficiency test for children aged 9-13. Schools could buy helmets with a discount of approximately 33%. In 1984 the government announced that they would pay a rebate of $10 to all purchasers of an Australian made, approved bicycle helmet. Also in 1984 a general publicity campaign was launched which made use of various media, including television, radio and brochures. A social marketing approach was the basis for the activities of the Road Traffic Authority to stimulate the use of helmets in Victoria (see also OECD, 1993). First, campaigns were targeted at parents of young children, later also at adult commuters and teenagers.

In order to measure progress in helmet wearing a series of observation surveys were carried out in Victoria. Depending on the age (children, adults) and type of cyclists (commuters, recreational), wearing rates increased from less than 10-30% 1983 to more than 40% in 1989 (Vulcan et al., 1991). After the law came into effect in 1990, usage rates further increased to 70-90%. The highest wearing rates were observed among young children (primary school), followed by adults (in particular among commuters); the lowest wearing rates were observed among secondary-school children.
In the first year after the introduction of mandatory helmet use a substantial reduction of the number of bicyclists with head injury were found in Victoria (37-51%). The mechanisms by which this reduction was achieved seem twofold: A reduction in the number of cyclists involved in crashes; and a reduction in the risk of head injury for cyclists who were injured (Vulcan et al., 1991).

Walker (1991) reports the results of an observational study to measure the effects of compulsory usage of bicycle helmets in New South Wales.
The law was introduced on 1 January 1991 for all cyclists sixteen years-of-age and older; on 1 July 1991 the law was extended to cyclists younger than sixteen years-of-age. Three months after the law came into effect, 77% of cyclists aged sixteen or older were wearing a helmet, and 84% of bicyclists older than twenty wore a helmet. The wearing rate of cyclists aged sixteen to nineteen was considerably lower: 46%. It was also shown that the new legislation resulted in a general decline in the use of the bicycle; it appeared that some cyclists have been discouraged from cycling because they do not own or do not wish to wear a helmet. The legislation and promotional campaigns in Western Australia (Healy & Maisey, 1992; cited in Goldenbeld & Wittink, 1993) also resulted in substantial increases of the wearing rate of bicycle helmets.

In addition to a reported decline in the use of the bicycle as a result of the mandatory wearing of a cycle helmet, Robinson (1996) points at negative safety consequences of this legislation: "Despite the large increases in the percentages of cyclists wearing helmets as a result of the mandatory helmet laws, the proportions of cyclists with head injuries admitted or treated at hospital declined by an average of only 13%. Furthermore, these reductions may not have been due entirely to increased helmet wearing [but due to other measures taken at the same time]. In contrast to small reductions in the percentage of head injured cyclists, there was an estimated decline of 36% in child cycle use in Melbourne, where matched pre and post law surveys showed a reduction in numbers of child cyclists fifteen times greater than the increase in numbers wearing helmets. In NSW, 36% fewer child cyclists were counted, 2.2 times the increase in child cyclists wearing helmets. Indeed, the comparison of counts of cyclists with injury data suggest the overall accident rate may even have increased, either because of increased risk taking by cyclists or reduced driver awareness of cyclists" (p.473).

In a number of states in the US (California, Maryland, Massachusetts, New Jersey, New York, North Carolina, Ohio) legislation on cycle helmets has been introduced or is pending introduction (Headlines, 1993; cited in Royles, 1994). In almost all of these laws helmet use is compulsory only for cyclists aged fourteen, sixteen or eighteen years or younger. Howard County, Maryland, became the first US jurisdiction to mandate the use of bicycle helmets for children (Coté et al., 1992). In a small scale observation study it was found that helmet use rates for children increased from 4% to 47% after the passage of the law in Howard County. In Montgomery, where a bicycle helmet promotion campaign (no legislation) was held in the same period, and in Baltimore where no bicycle helmet activities took place, no increases in helmet use were observed.

4.3.2. *Stimulating voluntary usage of bicycle helmets*

In Sweden, bicycle use has increased strongly during the past fifteen years. Ekman et al. (1992) report an increase of 40% from 1978 to 1984 among bicyclists from 15-84 years-of-age. At the same time the possession of bicycle helmets has increased as well: the number of helmets sold was 50,000 in the years 1975-1979 as compared with 2,500,000 during the period 1985-1989.
In 1985 a standard for bicycle helmets was published by the Swedish National Standards Committee, and from then on several promotional activities have taken place. Information materials were developed and distributed among schools and parents. No widespread mass-media campaigns were held in Sweden.

Since 1988, observational studies of bicycle helmet usage in Sweden have been carried out annually. The results of the measurements in 1994 (Nolén, 1995) show that the wearing rate for children (up to ten years) was 47% and for older school pupils (seven to fifteen years-of-age) approximately 25%. The wearing rate for adults (commuters) was 6% and for cyclists on public cycle paths 7%. Compared with the wearing rates in 1988, all cyclist categories have increased their wearing rates: an increase from 20%-42% for children up to ten years (an increase of 86%) and from 5-25% for school pupils (an increase of 392%). Total wearing rates are estimated (by weighing the wearing rates of children and adults) to be between 10-15%, following a slightly upward trend. However, since 1990-1992 usage rates hardly increased further. Briese (1992) presents the following reason to explain part of the stagnation in raising helmet use in Sweden: "How can children believe that a bicycle helmet is good for them, when adults don't use it? Teens throw their helmets away to show that they are no longer children" (p. 297).

A forum of experts ("Swedish Bicycle Helmet Initiative") sponsored by the Swedish government has launched a campaign targeted at children aged six to twelve, and is planning campaigns targeted at teenagers and elderly cyclists. The preparation of legislation is also discussed; the disagreement focuses more on when bicycle helmet use should be made compulsory (as soon as possible or only when wearing rates are sufficiently high) than on if such legislation is desirable. However, some bicycle organisations fear that - as in Australia - compulsory helmet use will lead to reduced bicycle use. The forum aims at: at least 90% helmet use among bicyclists aged twelve and younger in the year 2000, and at least 70% helmet use among bicyclists aged 13-18 and adults (Ekman et al., 1992).

In Denmark only minimal attention has been paid to the topic of bicycle helmets until the mid-eighties. In 1989 the Danish Road Safety Council started plans for a large-scale helmet campaign. In 1990 the first campaign was launched, aimed primarily at children up to the age of ten and their parents, and consisted among other things of competitions to find those school classes where cycling helmets were used the most. The campaign stressed that it was 'cool' to wear a helmet. The result was that the number of helmets sold in 1990 was around 350,000 as opposed to only 70,000 the year before. The sales figures indicate that 40% of all children up to the age of ten acquired a helmet (Flensted-Jensen, 1991; Danish Ministry of Transport, 1993). According to Flensted-Jensen the success of the 1990-campaign can partly be attributed to the distribution of the publicity material through schools and the "Children's Traffic Club" (40% of the parents of children aged three to six are members of this club). In 1991 a similar campaign took place aimed at children between 7 and 13 years-of-age. New bikes could be won for all pupils of the school with the highest wearing rate. About half of all schools in Denmark participated in the competition. No effects of the campaigns on actual helmet use are known, but according to studies of travelling habits focussing on children cycling, 68% of children between the ages of six and fifteen have a bicycle helmet. Only on approximately one in four trips made by children on an average day in 1993 was a helmet worn. As in Sweden, only few adults in Denmark wear a bicycle helmet, only 4% of those aged 16 to 74 report that they 'almost always' wear a helmet (Danish Ministry of Transport, 1993).

Following a campaign consisting of the (Danish) 'standard' nationwide programme with additional local activities in 1994, the wearing rates for schoolchildren aged six to nine years increased from 49 to 73%, for ten to twelve year olds from 11 to 50% and for children above twelve from 0 to 7%. In areas where only the standard nationwide programme had been held helmet usage only increased significantly for ten tot twelve year olds, from 8 to 25% (Behrensdorff & Arndal, 1994).

In Finland, the Central Organization for Traffic Safety collects measurements of bicycle helmet use yearly since 1990 (Tanttu, 1996). The results show a steady increase of bicycle helmet usage: from 4% in 1990 to 21% in 1996 (see Table below).

Year	Number of observations	Bicycle helmet use in Finland
1990	12.241	4%
1991	11.534	6%
1992	23.507	6%
1993	26.622	10%
1994	31.669	12%
1995	33.628	15%
1996	33.337	21%

Table 4. *Bicycle helmet usage yearly since 1990 in Finland.*

In Canada, in particular members of the medical profession were the first to stimulate the use of bicycle helmets. In 1991 the Canadian Medical Association started a campaign targeted at children aged five to fourteen and their parents. Leaflets were sent to more than 20,000 physicians and pediatricians; the leaflets included order forms to purchase bicycle helmets at reduced prices. In 1992 another campaign was launched by the Canadian Standardization Association with the release of two public service announcements to television stations across Canada. One announcement, aimed at a general audience, showed a wide cross-section of cyclists, including seniors, couriers, children and office workers; the second, which featured racing cyclists and riders of mountain bikes, was designed to attract the attention of an avid cyclists and preteen/teen audience (Focus, 1992; in Goldenbeld & Wittink, 1993). Cushman et al. (1992) describe the success of a three-year cycle helmet promotion campaign in Ottawa, Canada. From September 1988 to September 1991 commuter helmet wearing rose from 18% to 44%, an increase of 14% to 32% among recreational bicyclists was observed, and an increase of 2% to 21% among students. Morris and Trimble (1991) evaluated the effects of projects to stimulate helmet use at primary schools in Ontario, Canada. They conclude that such programs should be more than just information campaigns and that the presence of rebate schemes is crucial for success: helmet use had only increased at the school using such a rebate scheme in combination with an information campaign, whereas at other schools (a control site and a school that used only information materials) no increases were found.

In the UK, very low usage rates are reported; in 1987 Colyer et al. (cited in Royles, 1994) found that only 4% of the adult cyclists surveyed in Southampton wore helmets regularly. In recent years the helmet ownership among junior and secondary school children markedly increased, but usage remains low (11-13%, Royles, 1994). A television advertising campaign aimed at drivers and parents was launched in Autumn 1990 in the UK, which was followed by a second round of advertising in April 1991.
The purpose of the campaign was to convince parents of the importance of bicycle helmets in reducing injuries to child cyclists. Although no effects of the campaigns on actual helmet use are known, it was shown that there was a rise in the number of parents and children who thought that helmets would reduce the chances of head injury, and that there was an increase in the number of parents intending to buy helmets for their children (COI, 1991, cited in Royles, 1994). Current wearing rates are around 16% (Taylor & Halliday, 1996). While there are no plans to make the wearing of cycle helmets compulsory, the Department of Transport will continue with safety

campaigns to encourage cyclists, particularly children, to wear a cycle helmet.

The Allgemeine Deutsche Fahrrad-Club (ADFC) was the first organisation in Germany to mount a campaign promoting bicycle helmets in 1986. They encountered much interest, but also much opposition from the bicycle industry, from political representatives, and from cyclists. Objections involved the protective value of the helmets, fear of mandatory helmet legislation in the near future that would reduce bicycle use and sales figures, and doubts that German cyclists would accept helmets. Despite this opposition, helmets are now sold widely; it was estimated that in 1991, 1.5 million helmets were sold, and in 1992 sales of 2.5 million helmets were predicted. According to Briese (1992) bicycle helmet use by children up to twelve years is as high as in Sweden, and there are very few bicycle racers and tourers who do not wear helmets.

Except some local initiatives - usually at primary schools - no large-scale activities to promote bicycle helmets have taken place in the Netherlands. Seijts et al. (1995) studied the determinants of (non) wearing a bicycle helmet by children aged seven to thirteen in the Netherlands. 279 children used a helmet during a six-week pilot-project in three primary schools. The initial frequent usage of the bicycle helmet did not last long, because of reported inconvenience and negative reactions of other children and adults. Three months after the end of the project virtually no one wore a helmet anymore. At present (1996) a campaign to promote the voluntary use of bicycle helmets and to enhance social acceptance of helmet use is taking place at two primary schools in the Netherlands. The campaign is aimed at children aged four to twelve and their parents. A social marketing approach (see OECD, 1993) is chosen, and the target group has an active role in both the contents of the campaign and the evaluation. The results of the campaign will be used to assess the feasibility of a national campaign to stimulate bicycle helmets (Goldenbeld, 1996).

4.4. Attitudes to bicycle helmets

In an interview study held among some potential cyclist target groups in the Netherlands Goldenbeld & Wittink (1993) found that two types of cycling can clearly be distinguished: everyday cycling, which is only intended to achieve the practical purpose of transport, and recreational cycling, which places great emphasis on the elements of sportiness, adventure and physical relaxation. Regarding everyday cycling, people believe that the helmet represents an outward symbol of ineptitude, weakness or exaggerated fearfulness, they suspect the helmet will be uncomfortable, they say they feel 'stupid' if they stand out in a crowd wearing the helmet with ordinary clothes and they are not interested in trying out the helmet. For sporty, adventurous cycling purposes, the helmet could be considered as a standard and useful part of the total cycling equipment, the helmet represents an outward expression of skill, rather than ineptitude, the helmet fits into the image that one wants to present to others, people feel 'tough' or 'sensible' wearing the helmet rather than 'stupid', and persons who have never worn a helmet feel some inclination towards trying the helmet during holiday trips or rough terrain cycling. Goldenbeld & Wittink conclude that adults and children have no, or hardly any, intention to wear a helmet during everyday cycling voluntarily. With more adventurous forms of cycling, they are more inclined to wear the helmet, provided they are riding a special cycle and also wearing special, matching clothes.

Similar findings are reported elsewhere. For example in Denmark many (adults) find helmets troublesome and inconvenient to wear, and there is also a widespread belief that cycling is not dangerous enough to make protection necessary (Danish Ministry of Transport, 1993). In Australia, Elliott (1986; cited in Royles, 1994) found that despite high wearing rates, helmets still suffered from a highly undesirable image. In a questionnaire study carried out in the US, DiGuiseppi et al. (1990) report that 24% of (931) third-grade children in Seattle owned helmets but only half of them reported to wear them. They did not wear them because their friends did not, they had never thought about wearing one and because they found them uncomfortable. In the UK respondents of a postal survey were asked why they did not own a bicycle helmet (Colyer et al., 1986; in Royles, 1994). 44% stated that there was insufficient risk, 30% based their decision on cost, poor looks or lack of comfort and 24% stated that helmets were inconvenient.

In a Finnish interview study to find out why cyclists do not wear helmets, it is reported that most of the interviewees who rode without a helmet (76% of 287 cyclists) thought that the fact that the helmet was inconvenient to carry or leave somewhere was a factor influencing their decision not to buy one. Especially adults and elderly people were of this opinion. One in four of the respondents was of the opinion that only legislation making the use of cycling helmets compulsory would get them to wear one. While 42% of the respondents were opposed to such legislation, one in three favoured making the wearing of helmets compulsory for all cyclists. Women and elderly persons were the groups most favourably disposed towards compulsory use. A quarter of the interviewees favoured a limitation of compulsory use to certain age groups. Generally, the age groups suggested did not include the age group of the interviewees in question (Sipinen, 1993).

Taylor & Halliday (1996) conclude from an attitudinal survey conducted in the UK that it is more useful to distinguish between attitudes to cycle helmets on the basis of age rather than on the basis of gender or helmet status. In their study, young cyclists (up to fourteen) were shown to be very accepting of their helmet wearing, being attracted by the colour and design of the helmet. On the other hand, twelve to seventeen year olds were much more self conscious in a helmet, and whilst a few said that they felt safer or more conspicuous, many others stated that they liked nothing about the helmet. The results present the cyclist aged eightteen or more as one who attaches much greater importance to the practical and functional aspects of the helmets, such as cost and fit.

In a study conducted in Canada, Otis et al. (1992) conclude that a positive image of the bicycle helmet and good marketing techniques are crucial factors in the promotion of helmet use among young people. "Promotional messages should predominantly suggest that helmet use is synonymous with having fun, is attractive and pleasurable, and makes the wearing look sporty. (..) It should be shown as comfortable, adjustable, light, easy to store and convenient to use"(p. 288).

Stevenson & Lennie (1992) report on a two year community-based action research programme in order to develop strategies to encourage young students to wear helmets in Queensland, Australia. The use of bicycle helmets is not (yet) compulsory there. Wearing rates are considerably lower than in other states in Australia; about 5% of schoolchildren up to twelve years-of-age. According to these authors "it was evident from the discussion that no matter how much protection or comfort was provided, whether or not helmet wearing was regarded as trendy was the determining factor" (p.562), and "(...) It may be more useful for helmet designers, advertisers and retailers to position bicycle helmets as a fashion accessory rather than a safety device" (p. 564).

The reasons for non-wearing bicycle helmets are common in all studies: cycle helmets do not have an attractive appearance, they are uncomfortable to wear, peer pressure is sufficiently strong among young people to discourage their use. Parents of young children had often not thought about bicycle helmets, had not thought them necessary or had decided that they were too expensive (cf. Royles, 1994). On the other hand, when (Finnish) cyclists who wear bicycle helmets were asked why they used one, safety was most commonly cited as the reason for wearing a helmet (Heinonen, 1994). Next were the desire to show an example to others and previous experience of an accident involving the individual in question or a close relative. The helmet-wearing cyclists used their bicycles every day. Almost all of them said that they nearly always wore a helmet while cycling.
The wearing of a cycling helmet had become an established habit for these cyclists. 71% of the interviewees said that there were no problems or inconvenience associated with the use of a bicycle helmet. When dismounted during the course of a trip, the helmet was put in a bag carried for that purpose. Nevertheless, about half the respondents said they had to justify their use of a bicycle helmet to others.

Besides bicyclists' objections to the use of bicycle helmets, in many countries governments are reluctant to adopt legislation to make helmet use compulsory and cycling organisations are often strongly opposed to (the obligation to) wearing helmets. They argue that it could have a negative side effect in that an unjustified link may be established between cycling and danger, in that bicycle use may drop, and it does not fit into government policies which focus on the prevention of accidents (rather than reducing head injury severity) and on promotion of bicycle use. In addition, there is concern about the (lack of clarity about the) requirements that a good cycle helmet should satisfy and the degree of protection expected or demanded from the helmet (Goldenbeld & Wittink, 1993). Hillman (1993; cited in Royles, 1994) suggests that cyclists who wear helmets may think that they are better protected and could therefore adopt riskier riding techniques (cf. OECD, 1994).

4.5. Conclusions

Research has shown that the use of bicycle helmets can markedly reduce head injuries among bicyclists. However, in most countries only a small minority of children and adults wear helmets.
Compulsory usage - in several states in Australia and the US - of the bicycle helmet leads to substantial increases in helmet use. However, in

many countries it appears that such legislation is not feasible - both governments and cycling-organisations are not willing to make helmet use mandatory (e g. Germany, the Netherlands) or await high usage levels before planning to implement legislation (e.g. UK, Sweden). Therefore, bicycle helmet use must be promoted on a voluntary basis. This is not an easy task, because in general negative attitudes to the usage of helmets exist among (both adult and children) cyclists and among representatives of cycling and road safety organisations.

When cyclists are asked why they do not wear a bicycle helmet, the reasons given are a.o. that cycle helmets do not have an attractive appearance, they are uncomfortable to wear, and peer pressure is sufficiently strong among young people to discourage their use. Attitudes vary with age; young children are the most accepting of their helmet wearing, whereas negative attitudes towards helmet wearing prevail among adolescent and adult cyclists. However, cyclists who regularly use a bicycle helmet, usually do not complain about inconveniences associated with the use of the helmets. Wearing a helmet had simply become an established habit for them. Nevertheless, also these helmet-wearing cyclists often said they had to justify their use of a cycling helmet to others. Protection of the head was the most common justification.

Trippe (1994) concludes that educational programmes in conjunction with legislation appear to be the best way of increasing wearing rates, and that parental attitudes towards helmet wearing is a key component in increasing helmet use by children. The experiences in stimulating voluntary cycle helmet use furthermore indicate the important role played by the following factors (Goldenbeld & Wittink, 1993):

1. The spontaneous activities and efforts of civil activists and volunteers;
2. Aside from attention given to helmet use in the mass media, much attention has also been devoted to the bicycle helmet in local projects, in which government and private organisations tended to collaborate;
3. Funding schemes where helmets are offered at reduced prices;
4. A broad range of attractive, colourful and sporty cycle helmet designs
5. Clarity about the safety standards which a bicycle helmet should meet.

5. Other non-infrastructural measures

As stated in the introduction of this report, many types of 'non-infrastructural' measures to increase the safety of vulnerable road users can be distinguished. Only three selected areas have been discussed in the present report. This does not imply that other measures are not considered important as well. In this chapter a few of them will briefly be mentioned: characteristics of cars and trucks (car-fronts and side guards) can influence the severity of injury on the part of vulnerable road users, rules and regulations might affect the safety of vulnerable road users, as well as police enforcement, and telematics aids.

5.1. Motor vehicle characteristics

Accident opponents of pedestrians and cyclists are mainly cars (see OECD, 1996, Ch. 4). Certain provisions to cars might lead to reduced injuries when they collide with unprotected road users. A study conducted in the UK calculated that the reduction in fatal and serious pedestrian casualties resulting from vehicle design changes as proposed by the Experimental Vehicles Committee of the European Union would produce a net benefit in the year 2000 of 1,569 million ECU based on production costs or 1,389 million ECU based on consumer costs, giving a benefit to cost ratio of 7.5:1 or 4.3:1 (Lawrence et al., 1993). For instance, modifications of the design (e.g. the shape, length, and stiffness) of car-fronts can influence the severity of injury markedly (see, e.g. Janssen et al., 1990; Van der Sluis, 1993; Otte, 1994). Although trucks and heavy goods vehicles are the accident opponents of pedestrians and cyclists less frequently, the outcome of these accidents tends to be very severe. The fatal casualties in these accidents are usually road users other than the occupants of the heavy goods vehicles. Side guards, for example, can help to prevent pedal cyclists and pedestrians from being run over by the rear wheels of lorries (see, e.g. Riley et al., 1985). Near proximity and wide-angle mirrors on lorries are other examples. These mirrors are thought to improve the driver's view along the right side of the vehicle and to reduce the number of accidents involving right-turning lorries and two-wheelers to the right of the lorry. Since 1988 it is compulsory for Danish lorries above 6,000 kilos to carry these mirrors. A before- (four years) and after-study (four years) with control group did not demonstrate the expected safety effect on the relevant accident type. However, more than half of 2,000 lorries investigated had poorly adjusted mirrors, which might have contributed to the lack of effect (Behrensdorff & Hansen, 1994).

5.2. Rules and regulations

An example of a safety effect that can be attributed to a change of a rule is found in the Netherlands, where - in a pilot study in three cities - moped riders were to use the carriageway instead of the cycle track. Since the introduction of the moped in the Netherlands, Dutch law has required that they - being regarded as a type of bicycle - use cycle tracks wherever they are available rather than the carriageway. In practice, approximately 70% of the moped riders exceed the speed limits. Therefore, particularly inside built-up areas, the speed differences between mopeds and bicycles are much

larger than the speed differences between mopeds and other motorized vehicles. The idea was that it could be safer, for cyclists and other road users, if mopeds were directed to the carriageway. It was indeed shown that the measure 'mopeds on the carriageway' has exerted a favourable effect on injury related accidents in which at least one moped was involved (Hagenzieker, 1995); a reduction of 70% was found in the experimental areas, whereas in the control areas only a 20% reduction of these accidents was found (a trend that is similar to the national accident figures for this type of accident). The same result was found for the number of accident victims. In particular, accidents between moped riders and cyclists and between moped riders and vehicles have been considerably reduced. It is expected that within a few years Dutch legislation concerning the position of the moped will be adjusted; mopeds will then no longer make use of the cycle track inside built up areas.
Other traffic rules might have an influence on the safety of vulnerable road users as well, for example priority regulations at intersections. However, there hardly seems to be any research investigating the influence of rules and regulations on the safety of vulnerable road users.

5.3. Police enforcement

Police enforcement activities might also affect the safety of vulnerable road users. Two types of enforcement can be distinguished in this regard: enforcement directed at the behaviour of vulnerable road users themselves, such as red light violations; or enforcement directed at the behaviour of motorized traffic, such as enforcement of speeding. While an abundant amount of literature on the topic of enforcement exists (see, e.g. Zaal, 1994 for an overview), no effects of enforcement on the safety of pedestrians and cyclists are known. A small scale study in the Netherlands suggests that enforcement activities aimed at riding through red lights by bicyclists did not affect the behaviour of cyclists (whereas the same activities did affect the number of violations by car drivers; Twisk, 1993).

5.4. Telematics

Finally, the field of telematics applications can be mentioned as a possible means of increasing the safety of vulnerable road users. However, most of the (experimental) applications are developed for motorized traffic, and safety evaluations are not available yet. Recently, Levelt (1994) made an inventory of telematics projects for the benefit of vulnerable road users. A number of systems have been collected from literature and international correspondence. These systems are in different stages of development. Some are being developed specially for vulnerable road users, others have a somewhat broader target group, but are useful for vulnerable road users. Intelligent pedestrian crossings and electronic mobility aids for visually impaired people are two examples. Multi functional transponders are thought to be helpful for bicyclists. Access to public transport can be improved by the use of telematics in route choice, trip planning, and booking.

6. Conclusions and prospective measures

As stated in the introduction of this report, many types of 'non-infrastructural' measures to increase the safety of vulnerable road users can be distinguished. Only three selected areas have been discussed in the present report: education and training, measures to enhance visibility and conspicuity, and protective devices for bicyclists (bicycle helmets). This selection does not mean that other types of safety measures are not considered important. The topics of conspicuity aids and bicycle helmets were primarily selected, because in recent years many research reports have been published on these measures which have not been reviewed in other OECD-reports yet. The topic of education and training has been selected, because traditionally these are considered important measures to help increase the safety of vulnerable road users. Many reports on this topic have been published in the past two decades. A few recent examples of evaluations of programmes were presented that were aimed at children and elderly people, either as pedestrians or as cyclists. These are examples of research with the explicit aim of evaluating the effectiveness of a particular programme and are not yet covered in other OECD-reports.

6.1. Education and training

In dealing with the issue of road safety, the emphasis is generally placed on the training and education of the vulnerable road users themselves rather than on alternative measures such as town planning, infrastructural facilities, or the behaviour of other groups of road users. In general, education is often put forward as an effective preventive measure. However, evaluating precisely the effects of educational programmes is difficult, e.g. in terms of accident involvement. The examples presented in Chapter 2 illustrate the difficulties in evaluating educational programmes, and it appears that the effects of Traffic Clubs for children are still inconclusive. Contrary to the many educational programmes available for (young) children, very few intervention programmes for elderly pedestrians and cyclists have actually been implemented (and evaluated). One example of an evaluation of an education programme aimed at elderly pedestrians in Japan was presented. Although the study does not demonstrate an effect of this programme on accident involvement, a questionnaire study showed that the participants of the programme were enthusiastic about it. Especially the practical approach was valued by the participants. It is recommended that (more) effort is taken to develop and evaluate (practical) programmes specifically aimed at elderly pedestrians and cyclists.

6.2. Measures to enhance visibility and conspicuity

From the experiments reviewed in the chapter on measures to enhance the visibility and conspicuity of pedestrians and cyclists, it appears that retro reflective markings accentuating the form of the bicycle or a person (pedestrian), and stressing movements of these road users, are the most capable of having these road users recognized as such. One should not rely on detection distances, because these are much longer than recognition distances, and usually lead to too optimistic findings regarding the conspicuity of materials. Furthermore, expectations are very important factors in visibility. On average, when an observer knows what is ahead and about where it will be encountered, it will be detected at twice the distance that it will when the observer does not have those advantages. Conspicuity aids alone are not sufficient to secure recognition of vulnerable road users; other (infrastructural) measures should indicate to the drivers of motor vehicles that vulnerable road users could be expected on certain roads (e.g. the presence of bicycle lanes or pedestrian paths can set such expectations). The biggest problem is probably not the effectiveness of visibility aids but rather encouraging more widespread use of even the most basic aids in times of darkness. Only (a small) part of bicyclists use their lights and conspicuity aids for pedestrians appear to be used even less.

6.3. Bicycle helmets

Research has shown that the use of bicycle helmets can markedly reduce head injuries among bicyclists. However, in most countries only a small minority of children and adults wear helmets. Compulsory usage - in several states in Australia and the US - of the bicycle helmet leads to substantial increases in helmet use. Educational programmes in conjunction with legislation appear to be the best way of increasing wearing rates, and parental attitudes towards helmet wearing is a key component in increasing helmet use by children. However, in many countries it appears that such legislation is not feasible - both governments and cycling-organisations are not willing to make helmet use mandatory (e.g. Germany, the Netherlands) or await high usage levels before planning to start legislation (e.g. UK, Sweden). Therefore, bicycle helmet use must be promoted on a voluntary basis. This is not an easy task, because in general negative attitudes to the usage of helmets exist among (both adult and children) cyclists and among representatives of cycling and road safety organisations. The experiences in stimulating voluntary cycle helmet use indicate that spontaneous activities and efforts of civil activists and volunteers (in local projects), funding schemes where helmets are offered at reduced prices, and the availability of attractive, colourful and sporty cycle helmet designs as well as clear safety standards are important factors. There is also some concern that wearing a bicycle helmet may encourage cyclists to take more risks or lead to a decline in driver awareness of cyclists, under the misconception that cyclists are now better protected. This issue should be addressed in further research and can possibly be counteracted through education.

6.4. Other measures to increase the safety of vulnerable road users

These measures should *not* be taken *instead of other measures* such as infrastructural improvements (see OECD, 1996, Ch. 6); they should rather be seen as complement to other measures. Vulnerable road users can protect themselves, make themselves more visible and have (theoretical and practical) knowledge and skills acquired from education and training. However, they should not be solely responsible for their safety. A critical question arises about the balance between protecting the likely victims and other measures to reduce the source of dangers. One should not put the onus of protection on the vulnerable road users without any attempt to enforce, for example, lower speeds by the driver. There is also some concern that wearing a bicycle helmet or using reflective aids may encourage drivers to drive with less consideration, under the misconception that the cyclist is now much better protected and/or better visible. Drivers of motorized vehicles should be aware that they have a very important role to play in taking into account the safety of vulnerable road users; the topic of vulnerable road users should also be a topic in driver education (see also OECD, 1996, Ch. 2). Furthermore, characteristics of cars and trucks (e.g. soft car-fronts and side guards on trucks) can influence the severity of injury on the part of vulnerable road users, rules and regulations might affect the safety of vulnerable road users, as well as police enforcement, and telematic aids. More research in these areas can be recommended, because at present not much is known about the effects of these types of measures on the safety of vulnerable road users.

While continuing to develop effective educational and training programmes to encourage safe road user behaviour, and other non-infrastructural measures, policy-makers must be aware of the limitations of these and of the many ways in which current traffic policy and traffic rules do not accord with vulnerable road users' needs. Individual responsibility is important in improving road safety and preventing accidents, as well as public policy, but there is a real danger of simply trying to promote safer cycling or pedestrian behaviour by putting disproportionate burdens on cyclists and pedestrians rather than drivers (cf. McClintock, 1992). Urban and traffic planning using engineering measures in residential areas which reduce the amount of traffic and driving speed, improve road safety effectively. For example, in the Netherlands demonstration projects of so-called 'woonerfs' (where motorcars are allowed to drive at a walking pace only, no sidewalks for pedestrians are necessary and allowed) and '30 km/h zones' have shown reductions of injury accidents of sometimes more than 80% (SWOV, 1995). Currently, 300 out of almost 700 municipalities in the Netherlands have realised one or more 30 km/h zone. Measures such as these are in line with the concept of 'sustainable safety': a sustainable safe traffic system has an infrastructure that is adapted to the limitations of human capacity through proper road design, vehicles fitted with ways to simplify the tasks 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 (SWOV, 1994).

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